Operative Surgery

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This sixth edition is dedicated

to

the original author of this work

J. SHELTON HORSLEY, SR., M.D.

distinguished surgeon, author, and teacher

without whose inspiration and teaching

this edition could never have been accomplished

PREFACE TO SIXTH EDITION

The fifth edition of *Operative Surgery* was published in 1940, thirteen years ago. World War II started the following year and continued during the period in which a new edition ordinarily would have been published. Shortly after the war ended, Dr. J. Shelton Horsley, the senior author, died. Following Dr. Horsley's death it was thought for a time that it would be advisable to discontinue the book, for it was realized that his remarkable energy, broad surgical experience, and, above all, his mature wisdom would be sorely missed in the preparation of another edition. However, because of repeated requests from the publishers, The C. V. Mosby Company, and after one of us (G.W.H.) agreed to assume the responsibility of handling the details of the undertaking, it was decided to proceed with this, the sixth edition. It was obvious that the book would have to be largely rewritten, for the decade following the publication of the fifth edition had been one of remarkable change and progress in surgery. This progress was the result of a large number of factors, among them the occurrence of World War II. War has always stimulated new developments in surgery. Other factors, even more important than war, were the advent of the antibiotics, the development of satisfactory methods for storing blood, and, along with this, the belated appreciation of the necessity for the immediate replacement of blood lost during extensive operative procedures. Also of significance was the increasing appreciation of the necessity for more closely following the metabolic changes incident to illness and trauma, including surgical trauma. The first edition of this book, published in 1921, thirty-two years ago, called special attention to the importance of maintaining normal physiological balance and also dealt with those problems met with in general surgery and, in addition, certain conditions now cared for in the highly specialized fields of urology, orthopedics, and neurological surgery. Also included were procedures now handled almost exclusively by the plastic surgeons and other procedures in the province of the otolaryngologists. Yet the operations included in that edition were with few exceptions selected on the basis of a satisfactory experience with them by one surgeon. The same was largely true of the procedures presented in the second and third editions, published in 1924 and 1928, respectively. By the time of the publication of the fourth edition in 1937, the situation had changed so decidedly that Dr. Horsley felt it advisable to have an associate editor and also decided to include major contributions from specialists in neurological surgery, orthopedic surgery, and urology. The section on plastic surgery was written by Dr. John S. Horsley, Jr., who, though a general surgeon, was particularly interested in reconstruction and reparative surgery.

Because of the tremendous scope of surgery today and also as a result of the aggressiveness of the surgical specialties, there has been progressive limitation of the field described as general surgery. The authors believe that there is danger in

too high a degree of specialization and also believe it is necessary that surgeons be broadly trained, even though they may later choose to restrict their work to certain areas or systems within the body. Only by such restriction is one able to develop a high degree of proficiency in certain of the technics employed in special fields. With these considerations in mind, it seemed advisable to include a description of the commonly employed gynecological operations, for a large majority of such operations are performed by general surgeons. By the same token it seemed desirable to eliminate some of the more highly technical operative procedures employed in some of the special fields, notably in neurological surgery.

Because of the untimely deaths of John S. Horsley, Jr., and Donald M. Faulkner, the sections on plastic surgery and on orthopedic surgery had to be reassigned; plastic surgery to Dr. Henry J. Warthen, Jr., and Dr. Leroy Smith, and orthopedic surgery to Dr. M. J. Hoover. On account of the illness and retirement of Dr. C. C. Coleman, Dr. Charles E. Troland was asked to revise the section on neurological surgery.

We were fortunate to have Dr. A. I. Dodson again write the section on urology.

The gynecologic operations are ably described by Dr. Randolph H. Hoge.

A number of other surgeons were invited to make contributions on subjects in which they have developed particular interest and proficiency. We believe that their contributions add greatly to the value of this book Their names and titles and their respective contributions are listed.

We were especially fortunate to be able again to have Miss Helen Lorraine make all of the drawings for this edition, and her beautiful and accurate drawings add immeasurably to this book.

We wish to thank all of our contributors who have given so unstintingly of their time and talent to make this edition an accomplished fact. The untiring efforts and encouragement of Mrs. Daisy Spivey Fauntleroy in the careful preparation of the manuscript are gratefully acknowledged.

I. A. Bigger
Guy W. Horsley

Richmond, Virginia

PREFACE TO FOURTH EDITION

The fourth edition of this book is written under different conditions from those that existed when the first edition was published in 1921. Then I was working, at least to some extent, in urologic, orthopedic, plastic and neurologic surgery, as well as in so-called general surgery, and that edition was largely a record of my personal experience, with the addition, in instances where I had not performed certain operations, of described methods that appeared to me to be best suited for the lesion in question. In recent years, however, the specialties in surgery have become so distinct and aggressive that the general surgeon's field has necessarily contracted, while the specialties have become so elaborate that it would be impossible for any general surgeon to keep abreast with all of them. The methods of diagnosis in many of these specialties, as for instance urology and bronchoscopy, are now so complex that constant touch with them is required in order to be proficient in their use; and if a general surgeon devotes sufficient time to these methods of diagnosis to become really proficient in them, he must obviously neglect some portion of his work, as surgical pathology, which has a more direct bearing upon the fundamentals of general surgery. Therefore, regardless of the wishes of the general surgeon, much of the work previously done by him naturally gravitates to the various specialists.

Because of this condition, when the publishers requested a fourth edition of the *Operative Surgery*, I refused to undertake it unless I could have associated with me men who are well-qualified specialists and who could cover the fields that I attempted to cover in the first edition far better than I am capable of doing.

When this concession was made, I invited Dr. I. A. Bigger, professor of surgery at the Medical College of Virginia, to act as co-author of the book. Dr. Bigger has not only had extensive experience as a teacher in the Medical School of the University of Virginia and in the Medical School of Vanderbilt University before becoming head of the department of surgery of the Medical College of Virginia, but has done notable work in thoracic surgery as well as in general surgery. He is responsible for the chapters on surgery of the neck, thorax, breast, hernia, sympathetic nervous system, and some of the operations upon the extremities.

The operations upon the pericardium, heart, and intrapericardial portion of the great vessels, especially those procedures indicated in the treatment of trauma to these structures, have been chosen by Dr. Bigger as a result of his considerable personal experience in this field of surgery. Usually the operations described are selected because he has found them to be satisfactory, but in some instances several operations for the same condition are given and no attempt is made to indicate the method of choice.

Dr Bigger and I invited Dr. C C. Coleman, professor of neurological surgery at the Medical College of Virginia, to write on the surgery of the central nervous system and the cranial nerves; Dr. A. I. Dodson, professor of urology at the Medical College of Virginia and urologist to St. Elizabeth's Hospital, on urology; Dr.

John S. Horsley, Jr., assistant professor of surgery at the Medical College of Virginia and surgeon to St. Elizabeth's Hospital, on plastic surgery; and Dr. Donald M. Faulkner, orthopedic surgeon to Memorial Hospital and associate orthopedist to the Medical College of Virginia, on orthopedic surgery. Dr. Guy W. Horsley, who, though a general surgeon, is particularly interested in proctology, has given much aid in the preparation of the chapter on proctology. The assistance of others, for which we are grateful, is acknowledged in footnotes in the chapters in which their work appears.

This fourth edition follows the same general lines as the other editions and does not attempt to be an encyclopedic work. The methods described are those which either have been actually used by the author who writes of them or which seem to him to be the best for the lesion under consideration. Efforts have been made to base operative procedures upon physiologic function as well as upon anatomic structure and to retain physiologic function whenever consistent with the main object of the operation. For instance, in surgery of the stomach, a modification of the Billroth I method is described which we believe should be used in partial gastrectomy whenever possible, because the duodenum is the natural receptacle for the gastric contents.

Many new operative procedures are described which have not heretofore been published in a book, but none has been recommended which does not seem sound. At the same time such chapters as that on surgical drainage and on the underlying principles of the operations for malignant tumors have been retained. There are many new chapters, as the chapter on the surgery of acute abdominal conditions, and much of the work in the special fields has not heretofore appeared in any book.

Dr. Coleman, Dr. Dodson, Dr. John S. Horsley, Jr., and Dr. Faulkner have all included a number of new procedures in their various specialties, some of which are original with them.

Miss Helen Lorraine has very effectively added more than 500 new illustrations to this fourth edition.

The large amount of new material makes publication in two volumes necessary.

J. Shelton Horsley

Richmond, Virginia

I wish to express my appreciation to Dr. Horsley for allowing me the privilege of assisting in the revision of his book on Operative Surgery and for his generous help in this work.

I am glad to acknowledge my indebtedness to my associate, Dr. Harry J. Warthem, for his aid in correcting the manuscript as well as for his contribution on osteomyelitis Miss Helen Lorraine has made beautiful drawings which add so much to a book of this kind. My secretary, Miss Christine Provine, deserves especial mention for her care in preparing the manuscript

I A Bigger

Richmond, Virginia

PREFACE TO FIRST EDITION

In this book particular stress has been laid upon the preservation of physiologic function and the interpretation of the biologic processes that follow surgical operations.

Naturally, a knowledge of anatomy is essential for operative surgery, but in many regions of the body an effort to conserve or to restore as far as possible the physiologic function of the tissues involved in the operation has often been neglected. Merely following anatomical landmarks and making a beautiful dissection with accurately placed ligatures and sutures should not be the sole aim of the surgeon. These things, of course, should be included in the surgeon's ideals, but it is even more important that the operation results in the extirpation or correction of the pathology, and in the restoration of the physiology of the tissues or organs. One of the chief aims of this book is to emphasize those physiologic and biologic principles which, to some extent, obtain in every surgical operation.

The biologic processes that follow the application of surgical drainage, for instance, have been too frequently not considered at all and surgical drainage has been regarded as solely or chiefly mechanical. The treatment of fractures by metal plates or screws produces excellent immediate mechanical results, but a little study of the biologic processes following the use of metal plates should convince the surgeon that this is not a satisfactory operation. Physiologic principles, if logically followed, in operations for ulcer of the stomach and for resection of the intestine, appear to lead to certain definite technics, even though others may be anatomically and mechanically unobjectionable. The development of collateral circulation around an aneurism by partial or intermittent occlusion of the artery, as has been practiced by Halsted and by Matas, is often a much safer procedure than the immediate and permanent occlusion of the vessel. Developing a blood supply in the pedicle of a flap by the gradual dissection of the flap in different stages, insures against gangrene and makes possible better plastic results because it brings more nutrition to the reconstructed tissues. There are many other examples that might be cited.

No attempt has been made to include in this volume all surgical operations. Such an encyclopedia of operations is found in many excellent textbooks and systems of surgery. Every operation that I have described is either one that I have done or else an operation that appears to me to be the one best suited for the disease. Frequently, conditions are such that different operations may be indicated for what appears to be the same affection. In order to meet this situation, I have often described several operations, each one of which I believe, under certain conditions, would be appropriate. In this way the book is to a considerable extent a record of my personal experience.

All of the drawings are by Miss Helen Lorraine, except the illustrations of Dr. J. W. Long's enterostomy, which were drawn by William F. Didusch.

It is a pleasure to acknowledge my obligation to Mrs. A. C. Norris, my former secretary, who, in spite of her domestic duties, consented to help in the preparation of the manuscript for this book. She has greatly lightened the labor of its preparation.

My thanks are due Dr. W. T. Graham for many helpful suggestions about the sections dealing with orthopedic surgical operations.

J. Shelton Horsley

Richmond, Virginia

CONTENTS

VOLUME I

CHAPTER 16

CHAPTER 17

CHAPTER 18

CHAPTER 19

CHAPTER 20

CHAPTER 21

CHAPTER 22

CHAPTER 23

OPERATIVE SURGERY

VOLUME I

OPERATIVE SURGERY

VOLUME I

CHAPTER 1

GENERAL CONSIDERATIONS

Guy W. Horsley

A clear conception of the various technical steps is necessary for the proper execution of any procedure; but surgical operations are performed on living tissues and must be considered with regard to physiology and pathology in the living as well as from an anatomical point of view. Operations that look well on a cadaver will sometimes be unsuccessful on a patient. A beautiful operation that results in the death of the patient is not satisfactory surgery. While the mechanics of a surgical operation is important, it should not entirely dominate the situation. The object of a surgical operation is to save life, to relieve pain, and to restore function, and these three things in the order named should always be kept in mind. The technic of an operation should be chosen not solely because it appeals to a mechanical sense, but because it is biologically correct. The changes and reactions of tissues after operation must be borne in mind when selecting the technic for any surgical procedure.

It cannot be emphasized too often that surgery should be more a science than an art. A surgeon who is a dexterous operator and who skilfully amputates a leg that with patience and scientific application could be saved, is merely a good artisan, and is distinctly inferior to the surgeon who could save the leg even though he be a bungling operator. The ideal is to be thoroughly imbued with the principles of the biologic sciences, thoughtfully to apply these principles, and at the same time to be mechanically skilful.

The science of anatomy is essential to the mechanics of surgery. He would be a poor locomotive mechanic who did not understand the construction of his engine; and in operations on the neck, for instance, a surgeon who is ignorant of anatomy would be like the proverbial bull in a china shop. A knowledge of anatomy is essential to good surgery, but in the ever shifting problems of tissue repair and function, physiology is just as necessary. The principles underlying an operation are correct only if they conform to the laws of physiology and to the laws of repair of the tissue or organ that is affected. If we could get away from blindly

following what some one says merely because he says it, and do things because of reasons that have sound biologic foundations, we should undoubtedly do work more satisfactory to our patients and to ourselves.

Let us take an illustration from the practical work of a surgeon and see how thoughtful application of physiologic principles would have rendered a problem that appeared difficult easier to solve. Hyperemia is connected in one way or another with all surgical questions, whether they concern treatment of inflammation or repair of a wound. It has long been known that blood is an enemy of the tubercle bacillus, and that obtaining a good supply of healthy blood is a satisfactory method of combating tuberculosis. About four decades ago when a patient with tuberculous peritonitis and ascites sought surgical treatment he might have been subjected to one of several procedures. One surgeon would have advised opening the abdomen and letting the sunlight in; another thought it was best to dust the intestine with some special powder; still another believed in drainage with a single tube, or with multiple tubes. All these methods secured more or less satisfactory results. Each surgeon, seeing his patient recover after using his own method, thought that this was the only correct procedure. The situation resembled very much that described in a poem in an old school reader in which four blind men went to see an elephant. One fell against its side and thought the elephant was like a wall; another embraced a leg and declared it resembled a tree; the third grasped its tail and said the animal was constructed like a rope, and the last felt a tusk and concluded that the elephant was very like a spear. The moral was that though each was partly in the right they all were in the wrong. So all of these surgeons who were using different methods were unconsciously working on a principle that produced hyperemia, and it was this hyperemia, induced partly by draining off the fluid and so relieving pressure, and partly by handling the intestines, that cured the tuberculosis. It was many years, however, before this fact was acknowledged by the various partisans.

The surgical treatment of slow or threatened gangrene has also been much discussed. Carrel and Guthrie, after two experiments, concluded that the blood circulation in the leg of a dog could be completely reversed within six hours. They severed the femoral artery and vein just below Poupart's ligament and united by suture the cardiac end of the artery to the distal end of the vein, and the distal end of the artery to the cardiac end of the vein. After a few hours, when red blood was seen returning, they assumed that the circulation was reversed. It can now be stated, however, that it is impossible to reverse the circulation in this manner. In a series of experiments which have been reported elsewhere, it has been shown that when the severed femoral artery and vein of an animal are sutured together in a reversed direction, there is no real reversal of the circulation, and the arterial blood never goes more than a short distance below the knee and is then quickly switched back to the iliac veins through the dilated collateral vessels. Evidently what happened in Carrel's experiments was that dissection and severing the vessels paralyzed the vasoconstrictor nerves, and the dilated capillaries permitted red arterial blood to flow through unchanged. When the sciatic and crural nerves are divided in a dog, red blood appears in the femoral vein because of the extreme dilatation of the capillaries. Clinically this is often seen to follow an application of the elastic tourniquet which, if left on for even a short time and then removed, produces an

intense flushing of the limb until the temporarily paralyzed vasoconstrictors have resumed their function. Many useless operations have been done attempting so-called reversal of the circulation in threatened gangrene. The only good accomplished, besides affecting the vasoconstrictors, was damming back the venous blood and forcing the small amount of arterial blood that reached the tissues to stay longer than it normally would, and so deliver to the tissues more nutrition than would be possible when the arterial blood was quickly drained off by unobstructed veins.

Surgery of the gastrointestinal tract not infrequently suffers from the lack of application of physiologic principles. Indeed, real progress in surgery of the stomach and intestines since the advent of the roentgen ray is more indebted to the observations of the physiologists and the roentgenologists than to the clinical work of the surgeon. We now know that the lesser curvature of the stomach is the portion that is physiologically active and initiates gastric peristalsis; that resection of a portion of the lesser curvature interferes very greatly with the subsequent movements of the stomach, and consequently causes disagreeable symptoms; whereas resection of a portion of the greater curvature which is apparently physiologically "silent" produces no such effect. The sensitiveness of the mucosa of the intestinal tract to acid from the gastric juice increases from the duodenum down to and including the large bowel; so any direct communication between the stomach and the intestine below the duodenum is always fraught with the danger of an ulcer if the acid of the gastric juice is high. This danger increases with the distance of the anastomosed segment from the duodenum.

There seems to be much to confirm the views of Cushing in assuming that certain persistently recurrent peptic ulcers are due to nervous influences, an imbalance between the sympathetic and vagus impulses to the stomach—more frequently a predominant vagus stimulant. Crile's work on the excessive stimulation from the suprarenal glands in producing peptic ulcer is also of interest.

A gastroenterostomy performed on a young man with peptic ulcer whose stomach has a highly acid gastric juice will probably be followed by jejunal ulcer. The frequent occurrence of peptic ulcer in the duodenum does not show so much a lack of resistance of the duodenum to the acid of the stomach, but that the mucosa of the duodenum is the first tissue to receive the full effect of the acid gastric juice ejected through the pylorus and so bears the brunt of its attack. If the sensitiveness of the duodenal mucosa to the acid gastric juice were as great as that of the lower ileum, for instance, we would probably all have peptic ulcer. In marked obstruction of the duodenum and dilatation of the stomach, when the acid in the gastric juice is not excessive, gastroenterostomy is often a very efficient and satisfactory operation.

In partial gastrectomy, particularly if done for peptic ulcer, it is usually advisable to follow the general principles of the Billroth I operation in which the stump of the stomach is anastomosed to the duodenum, the natural receptacle for the gastric contents. Many cases of jejunal ulcer following a type of Billroth II operation when the gastric juice acidity is fairly high have been reported. When, however, most of the stomach is resected as in a subtotal gastrectomy, thus decreasing the supply of gastric juice and hastening the emptying of the stomach, almost abolishing gastric function, the incidence of recurrent peptic ulcer is lower than when a less radical partial gastrectomy is done.

In surgery of the intestinal tract, the marked difference in the physiologic function between the small intestine and the large intestine should be borne in mind. Even the physiologic function of the upper small intestine differs considerably from that of the lower small intestine. In the upper small intestine where the peristalsis is rapid and the bacterial contents are low, the open methods of operation can often be undertaken safely, provided an ample lumen is made for the intestinal tract; whereas the same open methods without any preliminary preparation in the large intestine would probably be followed by sepsis and peritonitis. Not only is the bacterial content of the large intestine much greater than in the small intestine, but the blood supply is less abundant. In the large intestine itself the right side differs very much from the left side. In the right colon the feces is usually liquid, the absorption of fluid is rapid, and a lesion frequently results in production of marked toxic products which are quickly absorbed; whereas in the left colon the function is chiefly that of a reservoir.

There are many problems in neurologic surgery that require some knowledge of physiologic principles in order to be settled satisfactorily. Spiller and Frazier have demonstrated that section of the posterior sensory root of the gasserian ganglion produces what is called "physiologic extirpation" of the gasserian ganglion. It has been known for years that a nerve which is injured on the central side of its ganglionic cells does not regenerate; yet when the operation of division of the posterior sensory root for tic douloureux was suggested, it was received with some skepticism. This operation is safer than surgical extirpation of the gasserian ganglion, and is followed by less trophic disturbance. The plugging of foramina in the skull from which neuralgic sensory nerves have been removed in order to prevent regrowth of the nerves has sometimes been done with metal screws. Because an iron screw can stop a hole in a piece of wood is not necessarily a reason for employing it in living tissue. On the other hand, some substance that does not cause reaction in bone is preferable. What happens after an iron screw is applied? Nature in an effort to extrude the irritating substance removes lime salts in its neighborhood, the bone softens, the screw becomes loose, and the nerve can grow around it.

The history of surgery of hydrocephalus contains many illustrations of the neglect of the appreciation of biologic principles in surgical operations. Various operations for this disease have been based upon an effort to secure drainage from the ventricles of the brain into the tissues of the neck with the idea that the excessive cerebrospinal fluid would be absorbed from this region. Tubes and threads of various kinds have been run from the lateral ventricle through the skull and into the tissues of the neck or scalp. There seems to have been very little consideration of how the absorption would take place after the mechanical features of the operation had been completed. It is obvious that a continuous injection of even a nonirritating fluid, such as salt solution, beneath the skin produces after a few days an exudate which, to a large extent, blocks the lymphatics and greatly retards absorption. When this takes place, it is only possible to cause the fluid to be absorbed by greatly increasing the pressure. Such pressure, if produced in the brain, would be fatal from compression of the brain. Consequently, even if the cerebrospinal fluid could flow unobstructed from the ventricles of the brain through a tube or along

threads into the neck, the intracerebral pressure necessary to force absorption would soon be so great as to impair the function of the brain.

That emotions have considerable bearing on the prognosis in certain cases of surgery has long been accepted. Cannon has demonstrated that fright or profound anxiety causes a stimulation, first of the sympathetics and then of the suprarenals. The action of epinephrine amounts to a prolonged stimulation of the sympathetic nervous system. Thus the body is put on what may be called a war basis: the circulation is more active, the heart beats faster, the pupils are dilated, respiration is accelerated, and metabolism generally is increased. Often there is so much glycogen released from the liver as to cause marked glycosuria, especially if the body is at rest; but if the emotions are accompanied by physical action, as fighting or running, this excessive amount of sugar may be consumed. The moral is that in some surgical cases it undoubtedly makes the prognosis better if emotions of fear or anxiety are allayed as much as possible. In diseases such as exophthalmic goiter, measures that abolish or diminish fear or excitement are of the greatest importance, and an operation should be so selected and performed as to carry out these indications.

Skin grafting and transplantation of organs or tissues are dependent on biologic laws. Surgeons who have had great experience in this type of work, such as Lexer and Davis, believe that skin grafts from others than the patient are practically never permanent. They either melt away at once, or, if they appear to "take," are later absorbed and replaced by connective tissue. It has been suggested that tests, as used for transfusion of blood, would be of benefit in selecting a donor for skin grafting; but even this has not seemed to have improved the end results. The transplantation of highly developed organs, such as a kidney, from one animal to another, even of the same species, is always a failure. The kidney may functionate for a while, but the fine biologic differences in the body fluids of the donor and the recipient cause degeneration, and the kidney eventually becomes a mass of connective tissue. This has been acknowledged by Carrel, Guthrie, and others who were at one time enthusiastic about the success of such a procedure. The reconstruction of channels, as the bile ducts, from tissues that have no resistance to the irritating discharges with which they must come in contact is also unwise. Operations in which strips of fascia, pieces of vein, and other tissue unaccustomed to the action of bile are used, ultimately result in failure, no matter how skilfully the mechanical part of the operation is done.

These are merely a few instances of what every surgeon sees in his work, and they illustrate the profound influence that the application of biologic principles has on surgical practice. Real progress in surgery lies not so much in cultivating the art of surgery and in striving after mechanical dexterity, which is important but can be acquired in a few years, as in the study of biologic principles that concern function, nutrition, metabolism, and repair of tissues, and in the thoughtful application of these principles to every operation and to every method of surgical treatment.

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CHAPTER 2

SURGICAL DRAINAGE

Guy W. Horsley

The biologic defenses of the body against disease, trauma, and the wear of age are wonderful, but they are not perfect. If they were perfect, man would live forever. Particularly interesting is the manner in which the body protects itself against injurious foreign substances. The epithelium-lined body cavities have more or less specialized methods of protection. The stomach, for instance, by vomiting, emits food that is spoiled and many drugs that are irritating or disagreeable to the taste and sometimes may reject substances that are thought to be nauseating or obnoxious even though they are not. The excessive salivation when nausea occurs probably tends to dilute the offensive material or to protect the walls of the mucous membrane. Vomiting undoubtedly is a habit that was acquired in the early days of evolution. The more refined drugs or poisons that are a result of chemical manufacture have not created a similar defense by the stomach and are often retained.

Foreign irritating substances in the rectum, the bladder, or the larynx are also expelled by muscular action. Irritating matter in the nose causes a profuse secretion, which tends to wash away the offending substance and may induce sneezing. An irritating foreign body in the eye causes a flow of tears in an effort to wash it away, and at the same time the spasm of the muscle of the eyelids is probably due partly to an attempt to expel the foreign body, as well as to protect against further injury.

In endothelium-lined cavities or in solid tissue there is an attempt to wash away foreign irritating matter. This is done by the pouring out of serum from the lymph circulation in the neighborhood of the foreign substance, which is accomplished by the reversal of the circulation in the local lymphatics, so as to empty their contents around the irritating material. This is really the chief basis of surgical drainage.

In surgical drainage mechanical measures that are followed by fortunate results would appear ridiculous if no biologic conditions existed. In preventing infection of a fresh raw surface, or in the so-called walling off of healthy tissue from the products of infection, gauze is often placed over the raw surface or as a coffer-dam in the abdominal cavity, and an abscess is drained through the center of this gauze packing. If we could convert this into a mechanical proposition and imagine that the pus was a solution of methylene blue and that it was flowing over this raw surface which had been covered with absorbent gauze to prevent contamination, we know that both the gauze and the wound would be deeply stained. This method of

protection, however, does act in a beneficial manner, and a clean wound is often by this means kept from septic infection. The drainage of a peritoneal abscess is practically always uphill and is usually successful. If mechanics were the only principle, how could an appendiceal abscess ever be drained by putting a tube down to it through the abdominal incision? The whole method of drainage really depends on the reversal of the circulation in the local lymphatics and is chiefly a biologic process. It is nature's effort to extrude a foreign substance.

A splinter in the finger which becomes mildly infected will provoke a discharge of thin seropus for days. This is nature's effort to expel the splinter. After it has been removed, the wound rapidly closes; and the lymph circulation, which was in part at least reversed in an effort to extrude the splinter, assumes its normal course, and probably twenty-four hours after the splinter has been removed there is no further discharge.

The peritoneum and its underlying structures in the abdominal cavity constitute an enormous lymph space, and the lymph is here abundantly poured out in response to an irritation. The insertion of a drainage tube causes a reaction in which there is a flow of lymph in an effort to expel the drainage tube. Drainage of the abdominal cavity prevents positive pressure in the septic region, and also the drainage tube is a stimulus for a reversal of the lymphatic circulation. The packing of a fresh wound with gauze causes a similar reversal of the lymphatic circulation; and though pus may flow over this gauze from a deeper focus, the lymphatics, instead of absorbing the pus, pour out lymph into and around the gauze to extrude it. The beneficial action of the cigarette drain, which is soon clogged with coagulated lymph, is comprehensible when we look on it as a stimulus for reversal of the local lymphatic circulation.

In regions of the body in which the lymph supply is less abundant than it is in the abdomen, unless the infected focus is very small it will be necessary to utilize gravity when instituting drainage, because there is not a sufficient flow of lymph to flush the septic cavity thoroughly and constantly, as there is in abdominal drainage.

CLASSIFICATION OF SURGICAL DRAINAGE

Drainage in surgical operations may be classified under three heads:

1. Drainage of solid tissue or endothelium-lined cavities:

   (a) Drainage of endothelium-covered tissues of the abdominal cavity.
   (b) Drainage of other endothelium-lined cavities, as pleura, joints
   (c) Drainage of solid soft tissue, as muscle, fascia, fat
   (d) Drainage of bone.

2. Drainage of inflammatory products from infected epithelium-lined hollow viscera, as the gall bladder and the urinary bladder.

3 Drainage of hollow viscera in order to restore function or to secure physiologic rest

1. Drainage of Solid Tissue or Endothelium-Lined Cavities

Considering, first (1-a), drainage of abdominal abscesses, we find, as has already been stated, that the abdomen has an enormous supply of lymph and that the

successful drainage of an abscess in this region consists, first, of relieving the pressure in the abscess cavity by opening it and inserting a drain; and, second, of inducing a sufficient reversal of the lymph circulation by the presence of the drainage material to cause the septic products to be washed away along the drainage track. If the drainage material reaches the abscess cavity so that the pus is not under positive pressure, and if the drainage is sufficient in amount and of the proper kind to act as a stimulus for reversal of the lymphatic circulation, so much lymph is poured out that practically a continuous irrigation is going on from the local lymphatics along the tube or track of the drainage material, and it is a matter of but little importance whether the drainage material is pointed up or down. But in other endothelial cavities (1-b), such as the pleura or the joints, where the lymphatic supply is much smaller than in the abdomen or where the configuration is such as to make the drainage difficult, gravity must aid and the problem becomes more mechanical than biologic. Drainage here should be at the lowest point possible.

Drainage carried down to sutured bowel frequently results in a fistula, particularly if gauze in the form of a cigarette drain is employed The reversal of the lymphatic circulation in the neighborhood of a recently sutured intestinal wound, which will direct the current of lymph to the drainage, interferes with the normal process of repair in the intestinal wound, causes a weak fibrinous deposit, and diminishes the nutrition of the repairing bowel; consequently, the sutures readily break down and a fistula results.

In drainage of muscles, fascia, and fat (1-c), gravity drainage must be considered, but the biologic problem is also prominent. An abscess in the thigh heals better if gravity drainage is instituted. The drainage material should be sufficient not only to carry off the secretion but also to excite the local lymphatics to reverse their circulation. The local lymphatics, being much less abundant than in the abdomen, cannot usually furnish enough lymph to cause the flushing out of the septic products, as occurs in the abdomen. In rapidly spreading inflammation, wide incisions and drainage are useful in relieving the pressure that is made by the binding fascia or skin, and in reversing the circulation of the lymphatics and so preventing absorption of much of the septic products into the main lymphatic trunks.

The old operation of "fence rail" incisions along the margin of an advancing erysipelas causes the pouring out of lymph from these cuts and the diversion of the lymph current, which would otherwise carry the septic products to further uninfected regions. The undermining of the skin and insertion of tubes or gauze drainage from point to point make the pouring out of lymph along the drainage material even greater than after a simple incision

That the reversal of the circulation of the lymph is the chief biologic process by which surgical drainage acts beneficially in solid soft tissue can also be recognized when there is a small abscess in a large amount of inflammatory exudate and it is impossible to locate the small abscess cavity If a drain is placed in its immediate neighborhood, the abscess frequently opens into the drain. It seems probable that this occurs because the lymphatic current attempts to extrude the drain and so the products of the abscess are carried in this direction and the abscess burrows to the tube.

The drainage of tissues whose lymphatic trunks have been clogged and where, consequently, edema is present depends on an effort to increase the lymphatic circulation or to create new lymphatic connections. In the operation of Handley, in which long threads of silk are placed under the skin in edema of the arm, lymphatic channels form along the threads. In the operation of Kondoleon, the deep fascia of the arm or leg is split in order to promote an anastomosis between the deep and the superficial sets of lymphatics and so to divert the lymph current from the superficial to the deep lymphatic trunks.

Local edemas that are persistent are usually caused by blockage of the lymphatic channels and not by interference with the blood circulation The edema that sometimes appears in the arm after a radical operation for cancer of the breast in which the axilla is thoroughly dissected is due to the removal of the lymphatics. If this immediately follows operation, it may disappear when the collateral lymphatic circulation is established; but when a late edema results, it is frequently because the lymphatics have become plugged with cancer cells; and such an edema is ominous. Resection of the axillary vein, if the lymphatics are in satisfactory condition, is followed by but little if any swelling in the arm, and that of a temporary nature. A phlebitis causes edema only when the lymphatics around the vein are involved in the inflammation.

Drainage of wounds after radical operations for carcinoma in solid tissue should always be done. This is not so much in order to carry off the fluids that may accumulate in the wound, as an effort to reverse the circulation of the lymphatics which may be induced to pour out their contents in the direction of the drainage tube and so to discharge, through this drainage, cancer cells that have been left in the wound or that may have lodged in the open lymphatics. This is an important step in many radical operations for cancer, as after operations in the neck or on the mammary gland.

Drainage of bone (1-d) involves problems of a somewhat different nature because of the structure of bone Bone is compact, rigid tissue in which lime salts are arranged in an orderly way On account of the rigid structure it is impossible for either blood vessels or lymphatics to form, or for the lymph current to reverse, as readily as in soft tissue Before drainage can be accomplished or any effective stand against infection can be made, the lime salts must be removed, so converting bone into what is practically soft tissue. For this reason in areas of inflammation bone is always soft Around an irritating substance in bone, whether accompanied by infection or not, lime salts are absorbed When this is accomplished, the offending material becomes loose and is prepared for extrusion. If, for instance, a piece of iron, as a screw used in plating bone, is inserted into a bone, the lime salts in the neighborhood of the screw and of the plate are absorbed The screws, which may have been very tight and firm when inserted, gradually become loose. This induced osteoporosis around the screws and the metal plate is just the reverse of what is desired when a fracture is to be repaired, and it accounts for the frequency of nonunion after the plating of bones

The numerous so-called abscesses at the roots of teeth are probably often the result of the reaction of the bone in the neighborhood to some material that was used in filling the cavities in the roots of the teeth Undoubtedly apical abscesses

frequently occur, but it is probably equally true that an osteoporosis sometimes interpreted as an apical abscess may be sterile and due to the reaction of the bone to the material with which the root of the tooth has been filled.

2. Drainage of Inflammatory Products From Infected Epithelium-Lined Hollow Viscera, as the Gall Bladder or the Urinary Bladder

Drainage here involves principles different from the drainage of an abscess that has formed in solid tissue. This drainage is not only for removing the products of infection but serves a double purpose in also giving physiologic rest to the infected organ. The drainage of a septic gall bladder that may be filled with pus carries off the products of the bacteria and at the same time gives rest to the gall bladder by preventing distention, and this removes both a stimulus for contraction and the tension that would occur on the distended walls. Drainage of this type does not have to be gravity drainage. If a sufficient opening is provided in the general axis of the peristaltic current, it is all that is necessary. In draining an infected urinary bladder, for instance, an opening made at the top of the bladder is as satisfactory in securing results as an opening at the bottom.

When these hollow muscular organs are contracted, a small opening will insure the viscera's keeping empty if it is made in due regard to the action of peristalsis. Even in such instances, however, the beneficial action of the drainage is not solely the removal of the contents of the hollow viscera or the giving of physiologic rest It seems highly probable that reversal of the lymphatic current is also of importance here. This appears to be borne out by the results of drainage of the bile tracts in inflammation of the pancreas. It is well known that chronic pancreatitis can best be treated by prolonged drainage of the bile tracts; and drainage of the common bile duct for this affection seems to be particularly effective. The work of Deaver and Pfeiffer on pancreatic and peripancreatic lymphangitis is interesting in this connection. They call attention to the anatomy of the lymphatic supply of the pancreas and its ultimate connection with the lymphatic supply of the bile tracts and gall bladder.

If infection of the pancreas can be through the lymphatic supply from the gall bladder or the bile tracts, as Deaver and Pfeiffer assert, it seems that the method of relieving this infection is to reverse the lymphatic current and cause it to be diverted toward the drainage tube and the incision in the gall bladder or in the common duct, just as the lymph flow is reversed in the drainage of an abdominal abscess. Septic products that would be carried in the lymphatics from the infected gall bladder to the pancreas are thus diverted to the drainage tube in an effort to extrude it. If this diversion can be maintained sufficiently long to permit nature to build up the resistance of the pancreas to the infection and repair the damage already done, the patient may be considered cured. But if the drainage tube is removed too soon, there is no further stimulus for a reversal of the lymph circulation, and the pancreatitis recurs.

Too early resumption of function after drainage of inflamed hollow viscera frequently results in a recurrence of the inflammation. This may be due to one of three causes, or more probably to a combination of three causes: (1) There may

Combinations that are effective have been worked out to a large extent empirically. Sometimes strands of catgut, silk, or strips of rubber tissue are inserted into a wound in which it is anticipated that there may be a collection of serum or broken-down fat on account of the nature of the wound. This foreign substance, the drainage material, directs the current of the lymphatic flow toward itself and so prevents an accumulation in the tissues which might later become a culture medium for bacteria. An open superficial abscess often needs no drainage material, for the necrotic products of the inflammatory process are a sufficient stimulus for drainage.

ENCAPSULATED FOREIGN BODIES IN THE PERITONEUM

If such foreign materials as gauze or cork are left in the abdominal cavity under sterile conditions, they are rapidly surrounded by a deposit of fibrin, as shown by Hertzler. This fibrin, which is coagulated lymph, soon is covered with endothelium and takes on the characteristics of peritoneum. If the gauze is left for a number of weeks or months, it may intrude into a neighboring hollow viscus and be expelled, as this may be the point of least resistance, and, consequently, of greatest pressure. Instances are recorded in which gauze that has been accidentally left after a surgical operation has been expelled by the bowel or by the bladder months or years later. Sometimes, however, the gauze is completely encapsulated with a cystlike wall and becomes so thoroughly infiltrated with fibrin that partial organization takes place. Portions of the gauze may be disintegrated and removed by phagocytes, and the connective tissue penetrating the rest of the gauze is so intimate that it may have to be dissected away with much difficulty.

CRITICISMS

The phrase "reversal of the lymph circulation" may not have been happily chosen, but we know no other that would be quite as satisfactory. The impossibility of an extensive reversal of blood circulation is fully appreciated, and it has been shown that a vein and its contributing branches would not function as an artery when an arterial current is turned into the vein

Surgical drainage is not a physiologic but a pathologic process. Lymph or serum is continually poured around an offending foreign body until the foreign body is removed or encapsulated. This lymph comes partly from the injured lymph channels and lymph spaces in the tissues and partly through the uninjured walls of the lymph channels which become more permeable with the hyperemia that is present when surgical drainage is necessary.

These are facts that are largely self-evident. The moot point is whether this process can be called reversal of the lymph circulation. This phrase was used because it seems that the current of lymph or serum continually poured out to the surface of the skin for days or weeks constitutes in a sense a circulation of lymph. This current, if it rises to the surface of the body and appears on the skin or mucous membrane, is not in the direction of any known lymph current and probably is a reversal, or at least a deflection, of the direction of the adjacent normal lymph currents. Then, too, this phrase seems to emphasize a phenomenon that many surgeons apparently ignore.

It may also be objected that "lymph" is used in rather a loose sense. It has been employed as indicating the thin, clear fluid that is found in the lymph channels and spaces of the body and that infiltrates the tissues in edema. In order to describe the phenomena of surgical drainage it appears to be necessary to use the words "lymph" or "serum" to indicate such fluids.

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CHAPTER 3

TECHNIC, SUTURES, AND INSTRUMENTS

GUY W. HORSLEY

The technic of an operation refers to the mechanical steps of the procedure and also to the manner in which the operator and his assistants execute these steps. Before the institution of antiseptic surgery, and particularly before general anesthetics were introduced, the time consumed in performing the operation and the style in which the operator worked were considered extremely important. Naturally, with a suffering patient without an anesthetic it was highly desirable to complete the operation as soon as possible. It was also found in preanesthetic days that a quick operation was usually more successful than one that was prolonged. In order to operate as quickly as possible, certain movements, methods of holding the knife, and of securing vessels, were considered good form, without which the proper speed could not be obtained. This is similar to athletic games, as in tennis, golf, or baseball, where the tennis racket, golf stick, or bat must be held in such a position or swung in a certain manner in order to secure the approval of experts on form.

When the surgeon made a practice of washing his hands only after the operation, and when instruments, hands, and everything that came in contact with the wound were loaded with bacteria, naturally the quicker the operation was done the better it would be for the patient, because the longer the wound was exposed to the septic hands of the surgeon or to the infected instruments or sponges, the greater would be the infection. Quick surgery in such instances was justly considered a vital necessity. There is not the same demand, however, for speed since the development of anesthetics and aseptic surgery. It is infinitely more important to do a clean operation gently than it is to do a rough operation quickly. The operation should be completed, however, as soon as is consistent with thoroughness, gentleness, and the complete application of the principles of aseptic surgery. The recent advent of chemical and antibiotic substances, which have done much to control and reduce infections, should in no way lessen the importance of gentle and meticulous aseptic surgical technic.

The instruments used should, of course, be such as may be needed in the performance of an operation, but effort should be made to use no more instruments than are necessary. Special instruments always carry the necessity of proving their worth. If an operation can be satisfactorily done with a sharp knife and sharp scissors and careful manipulations, there is no real need for special instruments, even though some surgeons require them. It is essential to have instruments that are reliable and of good quality. It is not only provoking to the surgeon to have a

dull knife and dull scissors, but it is unfortunate for the patient. In dissections, particularly around large vessels, dull instruments are dangerous, because undue effort has to be made with dull instruments to divide tissues when merely a gentle stroke of a sharp knife is all that is necessary. Consequently, the force and direction of the cut with a dull knife or scissors cannot always be as accurately gauged as with a sharp instrument. At one time it was fashionable to have forceps and scissors constructed with so-called aseptic locks, so they could be taken apart easily and cleaned. Such instruments frequently fell apart while they were being used and the joints soon permitted such play as to make the instruments undependable.

Suture or ligature materials are used in almost every operation. There is great difference of opinion as to choice of suture material and much is left to the individual surgeon's judgment. The sutures usually employed are silk, cotton, silkworm-gut, nylon, horsehair, catgut, kangaroo tendon, silver, tantalum, stainless steel, and bronze wire. There are certain operations in which there is almost unanimity of opinion among surgeons as to the type of suture material to be used. In most instances, however, the difference of choice is marked. Many operators use catgut for almost everything. The former objection to catgut, that it could not be properly sterilized, hardly exists today. It is true that sterilization of catgut is more difficult than sterilization of the nonabsorbable suture materials which may be boiled. By elaborate processes and repeated sterilization, however, catgut can be made entirely safe from the standpoint of sterility. Its rate of absorption can also be regulated to some extent by the size of the strand used, but particularly by impregnating the catgut with chemicals that make it resist absorption. The most used chemical is chromic acid products. By regulating the strength of the solution and the time during which the catgut is exposed to the solution, varying rates of absorbability are obtained. These rates, however, are not entirely accurate. The chief objection to catgut these days is that it is irritating to the tissues, particularly when impregnated with chemicals, and causes more reaction than do nonabsorbable sutures. If the catgut is not impregnated with some antiseptic it soon becomes a culture medium, and if the wound has been contaminated or if there is a hematogenous infection, the catgut may be the center of suppuration. When catgut is used in the mucosa of the gastrointestinal tract, it is, of course, rapidly absorbed, but if it is buried by successive layers, properly selected and applied, it will hold a sufficient length of time for union to take place. It has an advantage in operations upon the stomach, in that it is in the course of time completely absorbed if not too strongly chromicized, whereas if silk or cotton is used it is extruded toward the lumen of the stomach and sometimes becomes entangled in the mucosa and forms a source of infection and continued irritation In the vaginal mucous membrane catgut is not absorbed so quickly as in the gastrointestinal tract, but much more rapidly than in skin or muscle

Nonabsorbable sutures when buried often give trouble. It is not uncommon for sinuses to occur months after operations, when buried nonabsorbable sutures are used, and these sinuses will not heal until the sutures are removed. If nonabsorbable sutures are employed, the smallest strands that can safely be used should be chosen. The larger the bulk of material, the greater is the likelihood of trouble and sinus formation. When very fine silk is used to tie vessels and the aseptic technic is perfect, no trouble may result from the nonabsorbable suture, and in time such fine

strands are absorbed or encapsulated. Many surgeons, however, find that for buried sutures or ligatures absorbable material is, in the end, more satisfactory.

In plastic work catgut is not the ideal suture material. Its tendency to cause considerable reaction during the healing of tissues makes more exudate and frequently results in a more conspicuous scar than when nonabsorbable material, such as fine silkworm-gut, nylon, silk, or horsehair is used. There is not the same excuse for using catgut on the surface of the wound, where it can be easily removed, as when a suture or ligature must be buried. Fine plastic work on the skin, where an inconspicuous scar is desired, calls for nonabsorbable sutures.

When catgut is used in buried sutures, the smallest strand that will do the work should always be selected. For ligating most bleeding points, 00 plain catgut is sufficient. It must be remembered that catgut is absorbed, and the larger the strand the greater the burden of absorption placed upon the tissue. In addition to this, a fine strand of any material holds the knot better than a coarse strand. There is less likelihood of the knot slipping in a fine strand because there is more friction, due to greater surface compared with cubical contents in the smaller strand. It is better to use two fine strands of catgut than one large one, because they can be more readily absorbed. It is important in all sutures not to tie the knot too tightly as this constricts tissues unduly. This is particularly true of catgut.

Besides plastic work, special suture material is indicated in special regions. Marion Sims' well-known experiments showed that silver wire was the only material with which he could satisfactorily repair a vesicovaginal fistula. This is not only because it can be easily handled and nicely adjusted, but because metallic silver itself is mildly antiseptic and has no capillary action. Improved aseptic methods permit other suturing material to be used in repairing these fistulas, but the lesson taught by Sims is frequently neglected.

For bone, stouter suturing material must be used. Some have recommended heavy kangaroo tendon, but with the mechanical friction from the sharp edges of bone these tendons may not hold long enough. Moderately stout wire, particularly a cable of fine tantalum wire, is especially suited for work on bone, though where the strain is not great, tendon or chromic catgut is satisfactory.

When through-and-through sutures are used in the abdomen nonabsorbable material should always be employed Silkworm-gut, nylon, or silk is excellent here, though silver or stainless steel wire is used by many surgeons and has the advantage of being mildly antiseptic.

Various methods of closing abdominal incisions and other skin wounds are shown in Fig. 1.

For suture material in the intestines, cotton or silk is satisfactory, though some surgeons use catgut. The nonabsorbable suture seems to be extruded into the lumen of the intestine and rarely, if ever, causes trouble. If a single line of sutures is used in operations upon the intestine, and catgut is employed, it may be absorbed too soon and perforation may result This is because in order to secure a firm hold in intestinal suturing it is necessary to catch the submucous coat or to penetrate into the lumen of the intestine Where the suture penetrates into the lumen the rate of absorption of catgut would be so rapid as probably to be unsafe unless the catgut was chromicized to such an extent as to make it practically a nonabsorbable suture.

The thick walls of the stomach permit the use of catgut when there are several layers of sutures and when at least one of these layers is not in contact with the mucosa.

In large ventral hernias or in recurring inguinal hernias, a suture of fascia lata taken from the patient, according to the method of Gallie may be used. A strip of fascia can be utilized in the large needles as a continuous suture or an interrupted suture, or woven back and forth after the manner of a cobbler stitch or so-called basket weave. This suture should be reinforced by interrupted sutures of kangaroo

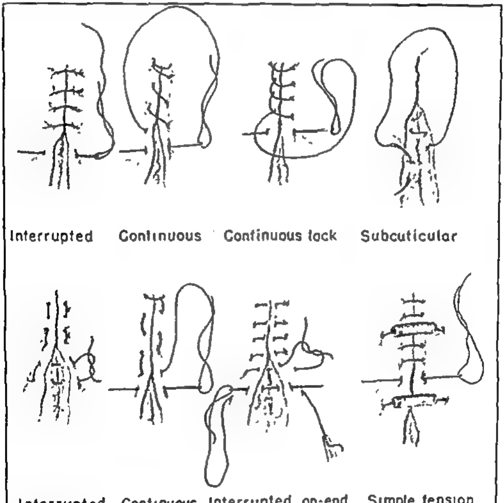

Fig 1 —Various methods of closing abdominal incisions and other skin wounds

tendon or silk at intervals The suture is obtained from the outer surface of the fascia lata of the thigh, either by a long incision or else by two short incisions, one above and one below, the strips being pushed down by a special instrument, or sometimes the loop of a small uterine curette will suffice The strips are tied in the Gallie needle with silk or catgut Two strips are united by tying the two ends firmly together with fine silk and then transfixing the ends with a suture of silk and again tying it This gives a long strip of fascia lata with a needle at each end, which can be woven back and forth to cover the defect

One of the most important procedures in the technic of surgery is tying knots. This can be done by any method that the operator finds best suited to his individual requirements. The all-important point, as taught by the old authorities, of making every knot a reef or flat knot has been greatly exaggerated, but undoubtedly a reef knot does hold better than the so-called "granny knot" (Fig. 2). The surgeon's knot consists of a double turn in the first tie and a single turn in the second. The double turn in the first tie secures the thread so that the second tie can be run down without the first slipping. The fallacy in this, however, is that when two wraps or turns are made instead of one, it is more difficult to run the first tie down smoothly and it is hard to tell how much pressure is being made on the tissues and how much is being taken up by the extra friction of the double wrap. In order to secure accuracy in tying large vessels or in mass ligatures it is much better to make merely a single wrap, as in the reef knot, and while this is tight, have it held firmly with a mosquito hemostatic forceps, which is strong enough to prevent the tie from slipping and at the same time is not strong enough to injure the thread. The second tie can then be run down easily. In any important suture or ligature it is best to make three ties to the knot instead of two. Then the knot will hold whether it is a "granny" or a reef knot.

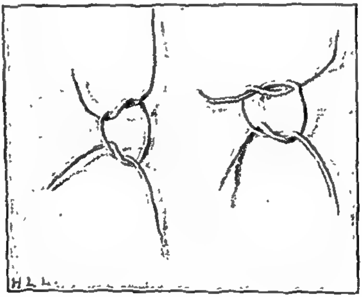

Fig. 2—Reef or flat knot, and "granny" knot.

In making a knot it is well to cultivate the art of tying it *with one hand*, as it frequently saves time and suture material. The finer the strand used for suture or ligature the more likely is the knot to hold, because there is more friction as the surface of the fine strand is greater in proportion to its cubical contents than in the coarser strand.

The reef knot lies flat because the loop on each side is over both strands of the thread. The tying of the reef knot can be best accomplished by concentrating the attention on one end of the thread and disregarding the other. If the first tie of the knot is so made that the right end lies away from the operator, the same end should then loop over the left end in the second tie in such a manner that it crosses the left end from above downward and toward the operator, and then passes

through the loop made by the left end. If this can be borne in mind, a flat or reef knot will always result, but even then, it might be wise to make a third tie.

Grant has described an excellent method of rapidly tying a knot with forceps so that the thread need not be touched with the hands, with great saving of suture material. If the operator wears good rubber gloves, there is no objection, from the

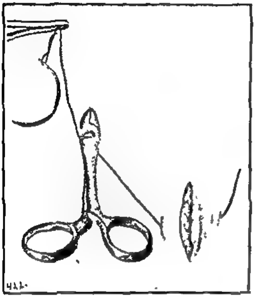

Fig 3.

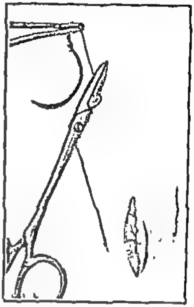

Fig. 4.

Fig. 3.—Grant's method of tying knot with forceps. The suture has been passed and forceps laid to the right of the thread.

Fig. 4—Forceps have made a loop in the thread, with the nose of the forceps up

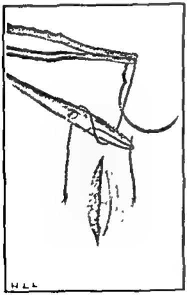

Fig. 5.

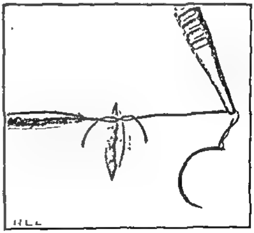

Fig. 6

Fig. 5—The tip of the thread is grasped with forceps

Fig 6—The thread is pulled through, forming the first tie of the knot.

standpoint of asepsis, to tying the knot with the hands, but not infrequently when there is a short end it can be tied more accurately and more quickly by this method of Grant than with the fingers It is also useful for tying in deep cavities where

the fingers or hands cannot readily reach (Figs. 3, 4, 5, 6, 7, 8, 9, and 10). The technic as described by Grant is as follows:

If the knot is to be tied in a transfixion suture or ligature, first transfix the tissues with the needle, which must be pulled through with the forceps, and catch the suture near the needle with forceps in the left hand. Pull on the thread until

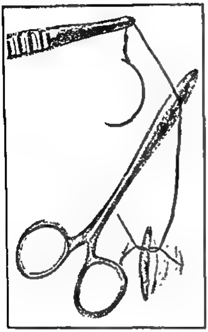

Fig 7.

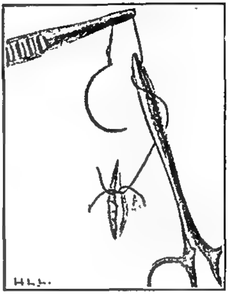

Fig. 8.

Fig. 7.—The second loop is made with forceps, this time with the forceps to the left on the under side of the thread.

Fig. 8.—The loop has been completed

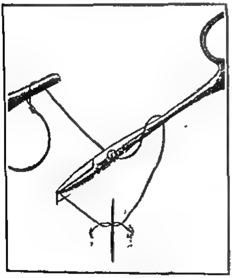

Fig. 9.

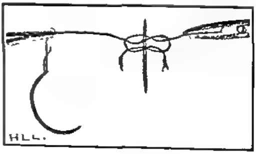

Fig. 10.

Fig 9.—The tip of the thread is drawn through.

Fig. 10.—The second tie of the knot is completed, making a reef knot.

the right-hand short end is only about 1.5 cm long. The long end should be proximal and the short end distal to the operator. Lay the point of the needle holder across and on top of the suture just below the point where the suture is being

held with thumb forceps pointing upward toward the tip of the thumb forceps, and make a loop as shown in the illustration. Then catch the short end of the suture with the tip of the needle holder and pull the short end through the loop while the left hand holds the long end of the suture taut with the thumb forceps. Next place the needle holder *beneath* the suture and make a second loop, catching the short end as before. This always results in a reef or flat knot.

Knots can be tied quickly in this way, with short ends and with a minimum amount of material. They can also be made in cavities in which it is difficult or impossible to use the hand or fingers.

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CHAPTER 4

PRINCIPLES UNDERLYING OPERATIONS FOR MALIGNANT TUMORS; TECHNICAL CONSIDERATIONS IN OPERATIONS FOR MALIGNANCY; X-RAY AND RADIUM BURNS

GUY W. HORSLEY

In order to have a clear conception of the surgical treatment of malignant tumors it is necessary to be acquainted with the essential facts known about them. A surgeon may not care to be his own pathologist in every instance, but he should at least take a sufficient interest in the tissue that he removes to study its histologic structure The surgeon will thus have rich opportunities for the understanding of tumors. Other things being equal, a surgeon personally acquainted with pathology is more competent to operate upon cancer than one who is not. Besides, there is nothing more interesting than to view the microscopic structure of a doubtful tumor. This stimulates the scientific possibilities of surgery and prevents the operator from being merely a "cutter."

A fatal technical error in suturing the intestine or in obtaining hemostasis may be directly traceable to the operation; on the other hand, the surgeon who does not recognize a malignant growth of the breast and operates upon it as though it were a benign tumor, making an incomplete removal, is just as responsible for this error which causes the patient's death months or years later as he who inserts a faulty intestinal suture The lack of knowledge of pathology is just as fatal as his technical incompetence in performing an operation. The patient who dies from a recurrent cancer that might have been prevented by the application of knowledge of pathology is just as dead as one who perishes because of bad mechanical technic at the operating table.

Operations for malignant tumors occupy a prominent place in surgical practice. The great increase in the incidence of cancer makes surgery for the relief and cure of neoplasms more important than ever.

Various causes have been suggested to explain this increase in cancer. One of the most prominent is the prolongation of life. The average expectancy of life is now about seventy years, and this increase has been chiefly from the decrease in the mortality rate of infants and children and of infectious diseases. A large part of this decrease is due to the work of public health services in the prevention of diseases such as malaria and typhoid, and in controlling epidemics. This decreased mortality in the young throws more individuals into what has been termed the "tropic of cancer," for cancer is pre-eminently a disease of middle and old age.

Dublin, of the Metropolitan Life Insurance Company, estimates that we may look forward to an increase in cancer rate for many years, as more individuals are reaching this "tropic of cancer" from the lessened mortality in children and early adult life. Then, too, more accurate diagnoses doubtless have something to do with the apparent increase in the incidence of cancer. Better pathologic diagnosis and more frequent postmortem examinations undoubtedly uncover many cases of cancer that were formerly otherwise classified. It will usually be observed that in populations in which the postmortem examination rate is low, cancer incidence is also low, and in areas in which the postmortem examination rate is high, the incidence of cancer seems to have increased. That careful examination and thorough necropsies will show more cancer seems to be a fact. But after making all due allowances for these two causes, there still appears to be an increase in the death rate from cancer that is difficult to explain.

Cancer, to be sure, is chiefly a disease of middle or old age, but it is not solely confined to these ages. Frequently sarcoma, a malignancy of connective tissue or of bone, attacks infants or children. While the death of little children has a more sentimental appeal and is justly held in high regard in the battle for the prevention and cure of disease, the middle-aged and elderly should also be considered. Frequently the death of a well-trained individual in the full tide of usefulness is both an economic and a civic loss.

THE CAUSE OF CANCER

Much has been said about the futility of cancer research: that after concentration on this problem for years in some of the best laboratories in the world the cause of cancer has not yet been discovered. In a sense this is true, but it should not be necessarily considered a crushing objection. Even in some of the acute infectious diseases, such as smallpox, which, certainly from a preventive standpoint, are treated effectively, we do not know the cause of the disease, and in those instances such as tuberculosis and diphtheria in which the etiologic relationship of bacteria has been proved, we are unaware of the cause of the bacteria; so we have merely gone in etiology one biologic step and have come up against a blank wall.

Cancer, like life, is somewhat difficult to define. Like life, too, we are generally aware of what it is: that it consists of an aggregation of cells springing from the tissue in which it arises, growing without law and order, and with an intrinsic tendency to destroy life. It is not contagious or infectious and is almost always painless in the early stages It was formerly held that cancerous tissue was without any physiologic function, but now we know that malignant tumors of the liver may actually secrete bile, that cancers of the thyroid will produce some of the thyroid internal secretion, and that malignant tumors of the adrenal gland stimulate sex changes. The search for some definite microorganism of cancer from which all cancers may originate has been rather definitely abandoned by most pathologists. It seems to be accepted that cancer doubtless springs from many causes and has various biologic etiologies

The rôle of heredity in the causation of cancer has attracted much attention. Little, in 1923, examined the family histories at the Eugenics Record Office of the Carnegie Institution at Washington, and became convinced from a study of these data that there is an hereditary predisposition toward cancer J. A Murray,

Tyzzer, Loeb, Slye, Lynch, Marsh, W. S. Murray, and others seem to have shown that genetics play an important part in influencing the incidence of cancer. Maude Slye has accumulated a wealth of material demonstrating that hereditary traits in mice profoundly affect cancer. According to Little, however, she has placed a wrong interpretation upon these facts, believing in a single simple mendelian unit which is recessive in inheritance to the noncancerous type; whereas the work of Lynch and of Little and his associates appears to show that while the hereditary influence is marked, it is not due to a single mendelian unit but to several factors and that it tends more to become dominant than recessive. This latter view seems to be substantiated by experiments with inoculated cancer in which the resistance to inoculation of cancer may be transmitted as a result of several different factors. Cancer, then, appears to arise chiefly in individuals who have inherited a lack of control of cells of the tissues, and in certain organs this control is more marked than in others. This lack of control may reside in the cell itself or in its environment. It is well known that cancer of the lips and face occurs much more frequently than cancer in the skin elsewhere. Cancer of the stomach is one of the chief causes of the deaths from cancer, while cancer of the adjoining viscus, the duodenum, which is more subject to ulceration than the stomach, is extremely rare.

Breaking away of cells from tissue control seems to be an important item in the initiation of cancer, and irritation which induces repair and consequently calls for a larger number of new cells than would otherwise be needed increases the chances for the cells to break away from control. In stabilized tissues, such as the palms of the hands and the soles of the feet, which have been stabilized by use and by repeated traumas during evolutionary times, control of the cells is so marked that even with numerous irritations primary cancer almost never appears.

But this breaking away of cells from control is not fully understood. Just what this control consists in is not well known. Merely severing the nerve connections in the tissues is not sufficient. Ewing has called attention to the fact that in artifical culture of normal cells, the cells practically never become malignant, and it is obvious that cells growing in artificial media would be without control from any surrounding tissue. Doubtless this lack of control from surrounding cells or tissue must be accompanied by some intracellular change and lack of control in the cells themselves, for otherwise it would seem that in an artificial culture of normal cells, there would be an ideal condition for the beginning of cancer, if lack of control from the adjoining cells were the essential and only factor.

CANCER RESEARCH IN THE LABORATORY

Cancer research work and the study of experimental cancer have taught us much about the nature of this disease. Ewing summed up very concisely the results of cancer research. First of all, he called attention to the unintentional production of cancer in their own persons by the early workers in x-ray. The squamous cell type of cancer of the skin and angiosarcoma in granulation tissue have been produced by this radiation in man and in the lower animals. There is a long precancerous stage before cancer actually develops after excessive x-ray stimulation. According to Ewing, "Cumulative changes in cell nutrition and metabolism, handed down through successive generations, and transforming the normal into malignant

cells, and the loss of the antagonistic balance between connective tissue and epithelium due to hyperemia and loss of elastic tissue in the derma appear to be illustrated in this process."

Radium, too, has proved a very effective cause of cancer. The series of cases reported by Martland in which malignancy developed in those who painted dials of clocks and watches with radium is extremely interesting. The small camel's hair brush with which the solution of radium was applied was often placed on the lips to "point" the brush. The radium usually produced a necrosis about the jaw, but a large portion of the workers who survived developed a type of osteomyelitis and finally sarcoma. Deposits of radium were detected in the bone, particularly the femur, apparently having been carried to the medulla of the bone by phagocytic cells absorbing the radium from the stomach. It is probable that this effect is produced mainly by the particles from the alpha rays.

The first experimental production of cancer by tar was effected by Yamagiwa and Ichikawa in 1914. No single application of an irritant is productive of cancer. It takes a long series of irritations, and it is this feature that is frequently overlooked. The painting of the ears of mice or rabbits with tar must be done at intervals over periods of months before cancer is produced. One or two paintings are not effective. This seems to throw decided light upon clinical cancer, because it tends to demonstrate that a series of irritations, continued for a long period of time, is essential for the production of cancer.

Little believes that in cancer the balance between organ and tissue system is upset and that the waste materials are formed faster than they can be healthily absorbed. He remarks, "Cancer is a very natural situation and not in the ordinary sense of the word, a disease. It is a region of the body in which growth processes have gotten out of control and cannot be brought back again. It is a local insurgency, a rebel against the normally contrasted processes of destruction and repair which if balanced, are able to avoid a crisis

"Because of the fact that cancer is due to upset balance between the organs and tissues of the organism, we find that its spontaneous occurrence is frequently correlated with a period or periods in the life of an individual when internal secretions and glandular activity in general are most likely to begin to wear out or to become unbalanced in relation to the other tissues of the body"

That there are many carcinogenic substances has been proved experimentally and by clinical observation The carcinogenic portion of tar that has been refined by Kennaway and Cooke has been producing rather regularly a malignant growth when injected into the tissues—carcinoma in epithelial tissue and sarcoma in connective tissue. J. W. Cook has made a substance from bile acid which after oxidation and dehydration and removal of the hydrogen and carbon dioxide, apparently reproducing artificially the changes that would go on in the human body, can cause cancer experimentally. He has synthetically built up the same material.

The discovery of the production of cancer of the stomach in rats when infested by a small nematode worm, *Spiroptera neoplastica,* which inhabited cockroaches, was made by Jensen. Local irritations may come from various different sources A cancer has been produced in the mammary glands of mice by Bagg, by rapid breeding and withdrawing of the young at birth In this way the mammary glands became

distended and doubtless irritated. It is probable that somewhat similar conditions in the human being may occur. The irritation or congestion of the mammary glands with or without actual lactation may overdistend the ducts and in the course of time produce sufficient irritation for the development of a neoplasm.

Experimental results which have been obtained by a number of investigators seem to show that there is some relationship between estrin, ovarian follicular hormones, and neoplasms of the breast. Estrin is a powerful stimulator hormone of the breast and uterus. Certain strains of rats and mice develop spontaneous mammary cancer in about 80 per cent of the females. Investigators have shown that if ovariectomy is done at an early stage in these mice the development of spontaneous cancer is diminished or practically abolished. Murray (1928) has shown that if male mice, which practically never develop cancer, are castrated and the ovary of a female mouse is transplanted subcutaneosuly, 7.1 per cent develop cancer in the mammary gland. It is an interesting fact that cancer of the breast occurs very frequently either in women who have not borne children or in those who have not nursed children. It would seem that the retained products of the mammary gland which are not drained normally through the ducts undergo some change which produces irritation. Thus Adair says, "Bagg, in our laboratory, began work on breeding experiments of mice. We know that our mice developed breast cancer in 5 per cent of our strain. He tied the nipple with a subcutaneous suture. The animals were bred, but could only suckle from the opposite side, so that the milk on the ligated side was locked in. The litter therefore nursed only half of the number of breasts. In this group the instances of carcinoma jumped from the normal 5 per cent up to 85 per cent. It is therefore obvious that research of animals is of vast importance especially when it can be hooked up with chemical studies and researches along *other* lines. We feel that there is a definite analogy between the nursing habits of mice from which we can eventually learn much of importance to the human race."

Little has produced cancer in the mammary gland in castrated male mice by implanting in them ovarian tissue which seems to stimulate an atypical growth in the undeveloped mammary gland of the male animal. It is doubtless true, too, that certain bacteria such as the *Bacillus tumifaciens*, which has been used by Blumenthal to inoculate rats, may cause cancer, probably not from any specific action of the bacteria, but from the irritation that they cause, as is produced by tar and other substances.

The mechanism of mutation, according to Ewing, may be responsible for cancerous change, and this may consist of three types: (a) a change in the gene; (b) translocation of a piece or pieces of one or more chromosomes; (c) abnormal distribution of one or more whole chromosomes. Such changes have been shown to arise in the course of chronic inflammation which often results in cancer.

The chicken or Rous sarcoma has been interesting in that a filtrable virus seems to have been responsible for the reproduction of this sarcoma in certain kinds of fowls. Murphy and his associates of the Rockefeller Institute have studied this carefully and believe that the agent responsible for these chicken sarcomas resembles very closely the substance that has been identified by Griffith and Dawson as capable of changing an undifferentiated pneumococcus cell into a specific strain. Murphy has suggested that these agents be called "mutagens."

Ewing remarks: "Out of this extensive field of research one seems justified in drawing the conclusion that there are many separate characteristic disease entities in the group now generally called cancer, and that observations made in one department may not be hastily transferred to another."

CLINICAL RESEARCH

In clinical research for cancer much has been done. Probably one of the most interesting results is the use of the Aschheim-Zondek test for the diagnosis of teratomas of the testicle or ovary. Zondek has demonstrated that in a case of chorioma of the testicle a secretion of the pituitary hormone, prolan A, is very marked. Russell Ferguson has elaborated this technic and by concentration of the urine can demonstrate early tumors of the testicle by using the principle of the Aschheim-Zondek test. This not only is very valuable for diagnosis but also serves to check up the radiation treatment. He finds that when the cells are practically destroyed, the rest is negative, but when the cells become active again, a positive test as in pregnancy occurs.

It has been the hope of the cancer research workers that some definite test for the early stages of malignancy will be found. From the nature of the disease, as has been outlined, and its protean aspects, both as to the clinical course and etiology, this does not seem probable, but to secure a reliable test even in one small group of tumors, such as neoplasms of the sex glands, is a high accomplishment. The hope for the cure of all tumors lies in early diagnosis and prompt treatment. While several workers have developed tests for malignancy, to date none has proved to be of much clinical value because of the great error in specificity. Papanicolaou's method of staining free cells in body fluids and tissue scrapings is immensely valuable in the early recognition of cancer, but here, too, a follow-up tissue biopsy is *usually necessary for a specific diagnosis.*

The various constitutional treatments for cancer have proved disappointing, and they have been too numerous even to mention. Those that have sprung from poorly thought-out or unscientific bases have been legion. A few have been worked out under scientific auspices. Thus, Blair Bell, Professor of Gynecology and Obstetrics in the University of Liverpool, noted that women who were working in factories where lead was used often aborted in the early stages of pregnancy. Upon examination of the products of the abortion, the fetus itself would usually be found intact, but there would be degeneration of the trophoblastic cells of the membranes. The resemblance in behavior of trophoblastic cells to cancer cells was striking. They not only penetrate into the uterus itself, but before they are connected with the oxygen of the blood stream, their energy is derived from splitting glucose, which is similar to the method by which certain cancer cells seem to thrive. Blair Bell thought that the resemblance in behavior of trophoblastic cells and cancer cells was so striking and the effect of lead on trophoblastic cells was so marked that an intravenous injection of a so-called colloidal lead, really a suspension of small particles of lead, into the patient with cancer would be an effective treatment. In a few cases there was benefit, and in some there appeared to be a cure. This aroused much enthusiasm, but the further result of this work was disappointing. The effect on the patient of this lead treatment when pushed is distressing. it produces a marked anemia, nausea and vomiting and very infrequently is any benefit derived. It has been

rather generally abandoned. One of the premises, however, on which Blair Bell's treatment was based, that is, that cancer cells derive their energy chiefly from splitting glucose instead of by oxidation, has been partially disproved by the work of Warburg, who found that cancer cells require a definite amount of oxygen and, in fact, most tumor cells are very sensitive to a lack of oxygen. Some normal cells also show a high aerobic glycolysis. Some malignant cells apparently have low glycolysis and high respiration, so that a high glycolysis is not essential to the growth of all cancer cells.

Cancer of the stomach, which looms large in the mortality of cancer, doubtless comes, as does cancer elsewhere, from some preexisting pathologic condition or abnormality. Hurst believes that in cancer with achlorhydria, the achlorhydria results from chronic gastritis and not from the cancer, but that any cancer with free hydrochloric acid has its origin in peptic ulcer.

The study of cancer is full of interest from almost any viewpoint—chemical, biological, pathological, or clinical. It should not be insisted that all research work must have an obvious utilitarian or clinical value. Time after time research work which appeared to be of merely academic interest has been proved of the greatest practical value. The old story of the early development of electricity is well known. When Michael Faraday and Joseph Henry invented the electromagnet and the dynamo it was considered merely a scientific toy. However, it should certainly detract none from the zest of any research to find that, in addition to its purely scientific interest, it may have some utilitarian or therapeutic bearing.

THE PRINCIPLES OF PROGNOSIS AND TREATMENT

There are only two methods of curing cancer that now receive approval from the highest authorities One is surgical removal, either by a knife or by a cautery or electrosurgery, and the other is by radiation, either by x-ray or radium or radioactive substances. A combination of these methods is often beneficial. The addition or subtraction of the different sex hormones and the use of nitrogen mustard gas and like substances have prolonged life and retarded the growth of malignant cells but have not cured any cases of authenticated cancer. A cancerous tumor consists of a number of cells, just as an army is made up of a number of soldiers. If they can all be extirpated at once, it is usually the best treatment, but sometimes because of the nature of the growth of the cancer or because of its infiltrating tendency and early dissemination, it is better to pick off the individual cells or soldiers as by radiation, than to attempt to remove them *en masse*. Laboratory research has done much in a therapeutic way not only in showing what type of tissue is radiosensitive and what is not, and so indicating the proper method of treatment to be employed, but also in providing a classification as regards the virulence of cancer. No one has done more in this respect than Broders, whose work is generally accepted.

The degree of differentiation of cancer cells is one of the surest indices to its malignancy The lower grades of cancer are usually less susceptible to radiation, though this is not universally true, because basal cell cancer is very effectively treated by radiation The higher grades with poor cytologic differentiation are usually more profoundly affected by radiation, though there are also some exceptions to this rule, such as melanotic carcinoma which is apparently but little affected by x-rays or by radium However, it must be borne in mind that an extensive cancer

even of low grade is more dangerous than a high-grade cancer in the early stages. It is impossible, for instance, to give a favorable prognosis from the histologic structure of well-differentiated cells in a case of cancer of the bowel which has existed for years and infiltrated much of the surrounding tissue, while a high-grade malignancy found merely in one small portion of the tissue may afford a better outlook. Other things besides the histologic structure of the growth must be taken into consideration when making a prognosis. If, however, it has been determined by the microscope that the cancer is of a low grade of malignancy and is reasonably accessible, a removal by some surgical procedure, either by a knife dissection or by cautery, or by a combination of these, is advisable. Frequently both radiation and surgery can be applied effectively, as in some malignant growths of the neck and of the breast. Surgery alone seems best in malignancy of the gastrointestinal tract except in sarcoma. Radiation alone, as in the lymphosarcomas, is often indicated.

Each case of cancer must be studied by itself. The early stages of the disease are often elusive, but early diagnosis and prompt intelligent treatment will cure a large percentage of patients with cancer who now unnecessarily go down to an untimely end.

These facts are not only interesting but have great practical importance in determining the prognosis and in deciding upon the treatment of malignant tumors.

METASTASES

The nature of metastases also has a distinct bearing upon the technic of operations upon cancer. The cancer cell itself is the essential unit of the malignant growth, and transplantation of this cell is necessary in order to reproduce the growth. Some tissues afford favorable soil for the metastasis of certain malignant tumors.

It is well known, for instance, that cancer of the prostate tends to metastasize in bone. Cancers of the breast also frequently metastasize in the bone, though not so commonly as cancers of the prostate. Epithelial malignant growths, especially in the abdomen, have a marked tendency to metastasize in the liver, probably through the portal veins, though usually cancer cells travel by lymph channels. Metastasis from cancer of the breast is practically always by the lymphatics, and though doubtless some cancer cells reach the blood vessels, they rarely survive in the blood stream except possibly in the portal circulation. Sarcomas, on the contrary, metastasize chiefly by the blood stream, and the common site of metastasis of sarcoma of the bone is in the lungs Cancers arising in organs that have a poor lymphatic supply tend to remain stationary for a longer time than in organs where the lymph vessels are abundant Thus, cancer of the colon and rectum, which have a relatively poor lymphatic supply, remains local much longer than cancer of the stomach, where the lymph vessels are abundant and metastases are early. Gastric cancer rarely metastasizes in the lungs but may follow the lymphatics to the neck Elderly people in whom the lymph supply is poor show a retarded metastasis, whereas in the young who are rich in lymph, metastases are more rapid Consequently, in elderly people, operation can usually be undertaken with more hope of cure than in the young

Some malignant tumors, as basal cell cancer, apparently do not metastasize at all. It seems probable that the cells of such tumors gain access to the lymph stream or to the blood, and are doubtless transported just as other cancer cells that

do metastasize. It is reasonable to suppose, however, that these transported cells find unfavorable soil at a distance from the growth, and consequently perish. This is interesting from a clinical standpoint, because resistance of tissues at a distance from this cancer appears to indicate, after removal of the cancer, transplantation of tissue from a distance, in order to inhibit the growth of any remaining cancer cells and to prevent recurrence.

TECHNICAL CONSIDERATIONS IN OPERATIONS FOR MALIGNANCY

There are certain general principles underlying the surgical treatment of malignant tumors which should in most instances be followed in any operation upon a malignant growth.

It is obvious that if a malignant tumor extends by cells being carried to tissues distant from the original growth and multiplying there, methods to promote this should be avoided. There should be no rough handling of the tumor during examination or during the operation. Drugless healers of certain cults who depend upon manipulation and massaging for a cure are capable of doing great damage in treating malignant tumors. Rubbing a lump in order to cause it to be absorbed particularly if it is a painless lump, is exceedingly dangerous. The fact that malignant growths in the early stages are usually free from pain unfortunately makes it possible for massage to be applied without protest from the patient—a treatment that would not be endured with an inflammatory mass. In a paper on the relationship of massage to metastasis in malignant tumors, Knox made a study of the effects of massage in cancer. A patient was observed on whom massage of the breast had been practiced before admission to the hospital. Metastases were scattered widely through the pectoral muscles, where metastases are usually very infrequently found. Experimentally Knox demonstrated that very gentle massage in certain transplanted cancers in mice, when the massage was done for a few minutes each day for a number of days, would set free particles of a tumor which would form emboli in the lungs and would produce numerous metastatic growths. The control experiments without massage showed a much smaller number of metastases.

If in metastasis cancer cells are transported by the lymphatics or by the blood stream, and are deposited elsewhere and grow, an incision into cancerous tissue through healthy structures immediately opens blood vessels and lymphatics to cancer cells and thus may hasten the extension of cancer by furnishing for the transplantation of the cells opportunities which without this incision would not have occurred. If an incision into a tumor must be made through healthy tissue, the incision should at once be cauterized with either the electric cautery or pure carbolic acid If the incision is exploratory and the growth is found to be cancer, a radical operation should be done at once. When a cancer is on the surface and is ulcerated, a piece of tissue from the margin of the ulcer can be taken without the added danger of opening lymphatics in healthy structures—but even here the wound should be cauterized and a radical operation should be done as soon as possible.

In cancers about the face and in cancers of the cervix uteri, tissue can be taken from the exposed ulcerated area with much less danger of spreading the disease than when the growth is deeper, as in the breast or neck.

Surgical operations for the cure of sarcoma are in principle somewhat different from operations for the cure of cancer. This is due to the difference in metastasis. *Sarcomas, as a rule, metastasize by the blood stream,* as has already been pointed out, and consequently a block dissection may be made without reference to the general lymphatic flow. An excision including a certain amount of healthy surrounding tissue with the tumor, and particularly if it can be made with the electric cautery, is satisfactory in many instances.

There are, of course, various degrees of malignancy in sarcoma of the bone, but it is somewhat more consistently virulent than many of the epithelial malignant tumors or cancer. The so-called giant cell sarcoma has been rather definitely proved by Bloodgood to be a nonmalignant tumor, and it is now called giant cell tumor instead of giant cell sarcoma.

In the osteogenic sarcoma it is doubtful whether radiation has any marked effect. The best treatment for an osteogenic sarcoma, whatever may be the subdivision, is resection or amputation. In occasional instances resection may be done, but this should not be a subperiosteal resection and should include the soft tissues near the periosteum. Instances in which resection is indicated are very rare, and it would be safer even then to amputate. As sarcomas tend to metastasize in the lung, and particularly as osteogenic sarcomas are likely to have such metastases, a careful x-ray study should be made of the lungs before the amputation is done, for this may save a futile mutilation.

Usually a diagnosis can be made by the history of the case and by a careful *roentgenologic study of the lesion. If this still leaves reasonable doubt, the patient* should be operated upon with a tourniquet and an incision made down to the growth and a frozen section examined. If the growth proves to be sarcoma, an amputation should be done without removing the tourniquet. Frozen sections, however, are not as dependable in lesions of the bone as in neoplasms of the soft tissues. Not infrequently myositis ossificans simulates the structure of bone very closely In such instances the study of the x-ray findings taken at different times and the histologic appearance should be correlated. If there is still serious doubt, it would seem to be the part of wisdom to amputate rather than postpone the operation too long. While amputation in sarcoma of the bone is often followed by recurrence, in some instances there is apparently a permanent cure after an amputation for osteogenic sarcoma of considerable malignancy.

Ewing's sarcoma and myelomas are quite radiosensitive, differing from other sarcomas of the bone in this respect. It was thought at one time that they could probably be entirely cured by irradiation, but it is now known that while they will often regress rapidly after adequate deep x-ray therapy, recurrence is the rule; consequently, after x-ray treatment, amputation or excision should be done. Coley's toxins seem more effective in this type of sarcoma than in osteogenic sarcoma.

Operations upon tumors of the bone require the most careful study The giant cell tumors are not malignant, although in exceptional cases they may apparently turn into malignancy This is so rare, however, as to be a decided exception and there is full justification for treating this type of tumor conservatively. Irradiation in osteogenic sarcoma is of but little value In the myelomatous type, deep irradiation is extremely helpful but should be followed by radical operation.

Myxomas of the bone are really a type of sarcoma and should be treated as osteogenic sarcomas. In sarcomas of the breast and of the fascia a radical operation is often curative. In sarcomas of the fascia the electric cautery or the endotherm should be used wherever possible. In lymphosarcoma, or lymphoblastoma, operation is utterly useless, and this neoplasm is powerfully influenced by irradiation. Some cases of lymphosarcoma of the neck have been free from recurrence for years after irradiation alone.

Hodgkin's disease cannot be benefited by operation, but it can be affected by irradiation, though it does not seem to be quite so radiosensitive as lymphosarcoma. A combination of irradiation therapy and nitrogen mustard therapy or a similar substance seems to hold this condition in check, but complete cures have not yet been obtained.

Certain portions of the body, as the jaw, the kidney, the coccygeal region, the ovaries, and the testicles, are peculiarly liable to have tumors from embryonic remains or rests. Some of these tumors, as the so-called mixed cell sarcoma or embryoma, or Wilms' tumor of the kidney, are very virulent. This tumor of the kidney should be treated, first of all, by deep irradiation with x-ray, and after the tumor has regressed a nephrectomy should be done. Apparently there is no definite cure of these tumors by roentgen ray treatment alone; though the tumor may so diminish that it cannot be palpated, it practically invariably recurs and the recurrence seems to become radioresistant. After the recession has fully set in, a nephrectomy should always be done. In other tumors springing from embryonic remnants, as adamantinoma of the jaw, there is doubt as to the malignancy, and such tumors are usually radioresistant. A block dissection of this type of tumor, keeping rather close to the growth itself, would be the proper treatment.

In carcinoma of the mouth, lips, and tongue the proper therapeutic procedure depends upon several different factors. In carcinoma of the lower lip, not infrequently adequate irradiation by x-ray or radium effects a cure. In carcinoma of the tongue or the buccal mucous membrane, the insertion of radon implants around the margin of the tumor and within the tumor itself often gives excellent results and is frequently curative. However, if the lesion is in the anterior portion of the tongue hemiglossectomy seems to give better results both as to survival and morbidity. When the bone itself is involved, the implantation of radon seeds in the soft tissue around the lesion, followed in a few weeks by resection of the bone, appears to be the most effective treatment.

When there is actual sarcoma of the jawbone, resection should be the treatment, though many cases that were formerly considered sarcomatous are now known to be either adamantinomas or other types of tumors with a mild degree of malignancy, where extensive resection will not accomplish any more than a limited close removal of the tumor. The implantation of emanations of radium can often be advantageously combined with the x-ray treatment in these lesions.

If resection of the tongue or jaw is essential and is to be extensive, it would be best to do a tracheotomy a few days before the resection and then block off the pharynx with moist gauze during the resection in order to prevent the aspiration of blood and mucus. If the growth is well localized on the tongue and mucous membrane, frequently its excision with the endotherm knife and suturing of the wound

with silk are satisfactory treatment. The use of the endotherm is a great help in the modern surgical armamentarium and will often enable the surgeon to remove growths safely that could not be attempted with sharp dissection.

Healthy tissue should not be incised with a knife to reach possible malignancy in order to make a biopsy unless a radical operation follows immediately if the lesion is malignant, and even then the wound should be cauterized with carbolic acid. If it is necessary to traverse healthy tissue in a biopsy, an endotherm knife or electric cautery should be used. The method of obtaining sections from a trocar and cannula can be employed in some instances. However, in cases sufficiently serious to demand a biopsy, an incision with the endotherm would appear to be more satisfactory in obtaining a larger block of tissue.

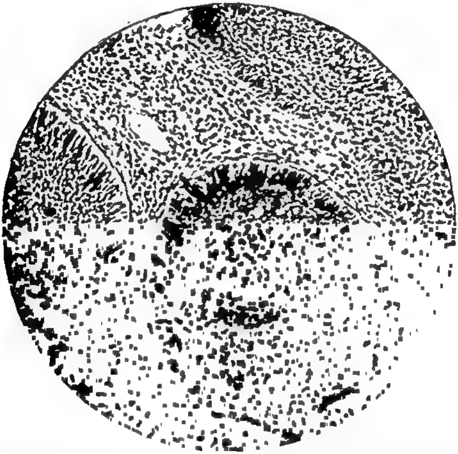

Fig 11.—Photomicrograp[illegible] P B There are large masses of epithelial cells surrounded [illegible] In certain areas this layer of columnar cells becomes very [illegible]pears, though it is present in most of the slide. There are n[illegible]

Basal cell carcinoma of the face does not metastasize except in very rare instances (Finnerud). This seems to be due to the natural resistance in normal tissues to a basal cell type of cancer. This resistance must be overcome before the growth can extend. The histology of basal cell cancer is varied probably because of its close relationship to the undersurface of the epidermis from which sebaceous glands, sweat glands, and hair follicles also arise (Figs 11 and 12). The spinous cell squamous cancer, however, often readily metastasizes at distant points, as in the lymph nodes of the neck Advantage may be taken of this peculiarity of the basal cell cancer in remaining local. After first excising the cancer, the raw surface of a

pedicle flap made at some distance from the margin of the cancer is transplanted to the raw surface left by excision of the cancer. This flap should be outlined at the time of operation and transplanted a few days later. In this way there is carried to the surface from which the basal cell cancer was excised, tissue from a distance whose natural immunity has not been broken down by the growth of the cancer. In small basal cell cancers about the face, simple excision with the cautery or the application of radium or roentgen ray is usually sufficient for a cure, but in the persistent type where there is recurrence in spite of such treatment and the growth becomes extensive, involving the bone or mucosa, the application of a pedicle flap taken at some distance from the cancerous growth is apparently of very considerable value. (Figs. 15, 16, 17, 18, 19, and 20.)

Fig. 12.—Photomicrograph of an extensive basal cell cancer which involved the antrum, upper lip, and a portion of the alveolar process and hard palate. This area is from the mucous membrane. The basal cells penetrated not more than 1 cm. from the edge of the ulcerated area. There is a tendency toward adenomatous-like *arrangement in certain areas. This is the* adenocystic type of basal cell carcinoma. (×155.)

When a cancer is of the squamous cell type, different methods must be pursued (Figs. 13 and 14). Transplantation of flaps in such a cancer has no effect in retarding the growth or in preventing recurrence. The recurrent cancer of the squamous cell type readily grows into a flap

It is important to differentiate the different types of squamous cell cancer. Broders has done very valuable work in calling attention to the difference in malignancy of squamous cell cancer. He has noted four grades, and of course the classification into grades may be more extensive. In Grade 1, there are many "pearls"

and advanced differentiation of the cells which approach maturity (Fig. 14). This is a mild type, and very rarely metastasizes into the lymph nodes. It grows slowly, and local excision is usually all that is necessary for a cure (Figs. 13 and 14). If a squamous cell cancer is of this type, a mutilating and extensive operation is not necessary. At the other extreme of the classification, Grade 4, there are no "pearls," and the cells are but slightly differentiated. This type is exceedingly malignant, and requires the most radical operation combined with treatment by roentgen ray and radium. Between these two extremes are the other grades of malignancy, which Broders classifies as 2 and 3, and not infrequently fractional numbers may be used to indicate a grade between the integers. This classification is of the greatest practical value to the surgeon, both as to treatment and prognosis, and should be determined before operation is completed.

Fig. 13.—Photograph of patient, A. T., aged sixty-two years, who gave a history of having had a lesion on the lower lip for ten years The growth was quite extensive. There was *one apparent metastasis in the left submaxillary region.* Biopsy showed a *low-grade carcinoma,* not more than Grade 1, which is shown in Fig. 14. The local growth was excised, the lip reconstructed, and a block dissection was made in the left submaxillary space The patient remained well as long as he was traced, about seven years after the operation. If a more malignant type had been shown in the biopsy, such an operation would have been unjustifiable, but with the grading it resulted in cure. (From Horsley, J S.: South M. J. 19: 292, 1926)

In cancer about the face with metastasis in the neck it is usually not practical to make a block dissection from the original focus in the face to the metastasis. The face, tongue, and neck are richly supplied with lymphatics The lymph nodes are grouped in certain definite areas. Apparently the cancer cells are quickly transported through these active lymph channels as emboli and rarely form growths in the channels themselves. Unless the primary lesion is so situated as to make it practical to do a block dissection from the growth into the neck, it is reasonably

safe to excise the primary growth on the face or tongue, preferably with the endotherm, and to do the operation on the neck as a separate procedure.

The electric cautery and the endotherm knife are the greatest help in operations upon almost any malignant tumor. In block dissections, if the cancerous tissue is opened, it should at once be cauterized with the electric cautery or the endotherm. The wound should be flushed out at intervals with salt solution to wash away any cancer cells that may have been spilled. Theoretically it would be safer to do the whole dissection with the electric cautery or the endotherm. As a matter of fact, however, the cautery or the endotherm, if used about the large vessels, necessarily would be dangerous because of the possibility of secondary hemorrhage. It seems safer to do a block dissection of the neck with a sharp knife and

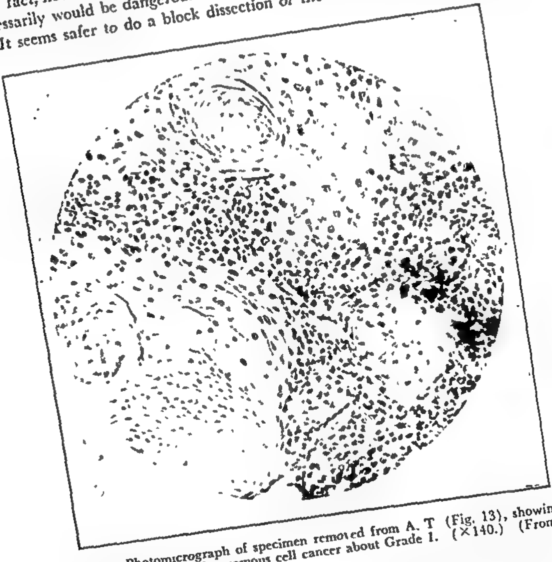

Fig. 14.—Photomicrograph of specimen removed from A. T (Fig. 13), showing mature cells, numerous "pearls," and squamous cell cancer about Grade I. (×140.) (From Horsley, J S · South M. J 19: 292, 1926)

to use the electric cautery or endotherm at suspicious points (Fig. 21). If the cancer is very extensive, radium emanations or needles may be inserted at strategic points, particularly at the base of the neck or where the cancerous tissue seems rather near the margins of the dissection.

In block dissection for cancer of the neck or breast, drainage should always be used, preferably through a stab wound. The desirability of this has been emphasized in the chapter on drainage. Malignant cells that are left behind may be absorbed into the open lymphatics, but if drainage is instituted, the cells which

float in the lymph serum poured out into the wound may be drained externally, and the drain itself promotes a reversal of the lymph flow so that cells already in the lymph channels may be washed toward the drainage tube.

In cancer of the breast the principle of block dissection introduced by Halsted and independently by Willy Meyer has been fully adopted. The principle is to remove the breast and surrounding tissue in one mass Handley has shown that cancer cells of the breast not only are carried by the main lymph trunks to the axilla and probably through the lymph vessels to the fascia and tissue over the recti muscles and to the abdomen, but according to him they spread in lymph channels in columns radiating from the original focus into the subcutaneous tissue.

Fig. 15.

Fig. 16.

Fig. 15—Basal cell cancer before operation. Mr. G. K P

Fig. 16.—Condition of the mouth sixteen days after operation The slough has not yet fully separated. (See Fig 15.) The flap in the neck has been outlined but does not show here.

Many of these cells near the original tumor die and the lymph channels in which they lodge disappear. Consequently, it is not necessary to make an exceedingly wide skin incision for excision of cancer of the breast, which in the early development of this operation appeared to be essential. The amount of excised skin should be generous, but it is very important to make a wide undermining dissection, including in the mass to be removed the subcutaneous fat and fascia, in which *tissue Handley has shown the cancer cells grow in a radiating manner*

In cancer of the stomach and intestines, the principle of block dissection should always be followed Dissection of the mesentery and the attachments of the stomach or the bowel begins at the farthest margin along the proposed line of division. The stomach or intestine should never be opened until all of the mesenteric and other attachments have been separated, the vessels tied, and the surrounding tissues packed off with gauze. If a lymph node or a metastatic area has been

accidentally incised, it should be cauterized at once. The difference in the virulence of cancer of the large bowel and cancer of the stomach may be at least partly attributed to the greater lymph supply of the stomach.

Teratomas of the testicle and ovary, though they may show fairly well-differentiated cells in some areas, are very sensitive to irradiation. A teratoma, or embryonal carcinoma, of the testicle, even if small, should first be submitted to irradiation, preferably by roentgen ray, and then the testicle should be removed.

Fig. 17.—About a month later. The slough has separated, and the wound has partially healed. The flap in the neck has been gradually dissected free, and its undersurface is partly covered with Thiersch grafts. It is ready to be denuded and transplanted to the region of the upper lip, according to the method described in the text. (See Fig. 16.) Several years later the patient was apparently cured.

It would seem, however, that the extensive operations that have been devised for this tumor of the testicle, including not only removal of the testicle and cord but resection of the retroperitoneal space, are unnecessary and unjustifiable, because modern deep x-ray therapy, accompanied in certain instances by the application of radon implants if necessary, offers a far more favorable prognosis as to cure than even the extensive block dissection and is at the same time less dangerous. If the growth is at all extensive, operation of any kind would probably be unwise, but in the early stages local excision after irradiation, and followed by irradiation, will doubtless give the best results.

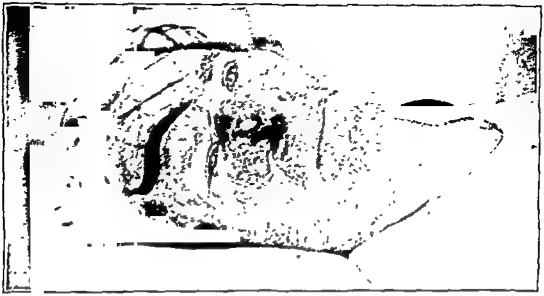

Fig 18.—This patient, Mr. C. B, had a recurrent basal cell carcinoma of the right cheek and adjoining portion of the nose that had been treated by roentgen ray and radium and by operations The photograph shows the growth excised with the electric cautery and the outline of the flap from the forehead which is to cover the raw surface from which the cancer was excised.

Fig 19

Fig 20

Fig 19 —Mr C. B The flap has been sutured in place, and a soft clamp is applied to the flap a short time each day in order to encourage the blood supply from the region of the excised cancer to the flap

Fig 20 —Photograph of the completed operation

Operations for malignant tumors occupy a considerable portion of the general surgeon's work. It seems essential for him to study the type of malignancy for which an operation is undertaken, and to understand as far as possible the nature of the growth as well as the resistance of the patient who is the host of the tumor

Fig. 21.—Drawing showing block dissection [illegible]
the borders of the gum, the parotid gland, and
moved in one mass, including the jugular vein,
tissue, along with the jawbone and the parotid gl.

ROENTGEN RAY AND RADIUM BURNS

It may be of interest to consider briefly the surgical treatment of radiologic burns in which there is no malignancy. When they occur they often follow the use

of the roentgen ray or radium in the treatment of cancer. They are very painful and are difficult to cure by the usual methods.

These burns require a different principle of treatment from what is necessary in an ordinary ulcer. This is because the rays from radium or the roentgen ray have a very pronounced stimulating effect upon the endothelial cells of the intima of blood vessels. When radium or roentgen rays destroy normal tissue, the effect of the rays that penetrate through tissue that still lives causes such a marked proliferation of the endothelium of the blood vessels that the lumen of the vessels is greatly diminished or the vessels may even be converted into cords (Fig. 22). For

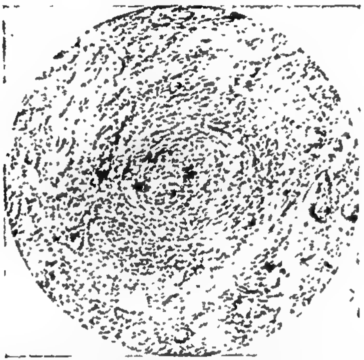

Fig. 22.—Photomicrograph of tissue from a radium burn. The vessel has been entirely occluded by the proliferation of endothelial cells. The muscular coats of the walls of the vessels are shown. In other areas not shown here, small new vessels are seen that are normal. (×100.)

this reason the lesion continues as an ulcer and is exceedingly slow to heal. The local tissues are ischemic, and this not only prevents repair of the tissues but causes ischemic pain in the nerves. If Thiersch grafts or free whole skin grafts are transplanted to such a burn, they do not live because the nutrition of the surrounding parts is greatly diminished by the partial or complete obliteration of the lumen of the blood vessels and not enough blood can be transported to support the tissue already there, much less bear the additional nutritive burden of sustaining the grafts. It is, then, essential in the treatment of these lesions that are at all extensive to provide not only an epithelial covering but a new blood supply that will support the covering and at the same time carry blood to the poorly nourished tissue involved in the burn The graft, therefore, should always be a flap with a pedicle and the blood supply that comes through the pedicle should be developed by gradually dissecting the flap free as described in the section on Plastic Surgery. In this way not only will the epithelial covering have its proper nutrition, but the poorly nourished tissue beneath will also have an additional blood supply.

This principle may be used in repairing defects caused by radium elsewhere. A large fistula in the bladder following applications of radium to the cervix uteri

cannot be repaired by the ordinary technic for closing a vesicovaginal fistula but demands transplantation of flaps of mucosa or other tissue that will be permanently furnished by nourishment through a pedicle.

When the tissue affected by irradiation can be fully removed down to a good blood supply, free grafts may be applied.

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CHAPTER 5

INFECTION; SHOCK; HEMORRHAGE; BLOOD TRANSFUSION; FLUID ELECTROLYTE BALANCE

EVERETT I. EVANS

The introduction of potent antibiotics for the prevention and treatment of surgical infections has greatly lessened the hazards of "operating room contamination," but success in surgery still depends largely on strict adherence to the principles of asepsis and wound care laid down by Lister in 1879.

PREPARATION OF THE OPERATIVE SITE

The preparation of the patient's skin for operation is not done in the most efficient manner in many clinics. Surgeons often place unwarranted faith in germicides and antibiotics and are not aware that preparation of the patient's skin should follow the rules of ordinary body cleanliness. Soap and water remain the best agents for cleansing the skin and for the removal of bacteria.

The surgical committee, in close cooperation with the nursing service, should have clearly defined technics for preparing the skin for the common surgical operations.

Facilities and personnel should be available in well-ordered hospitals for preparation of the operative site at least twelve hours before operation. The area should be cleansed with soap and water before it is shaved Shaving is best done by a sharp, straight razor, but nowadays few persons are trained in the use of straight razors. Shaving is done safely with one of the ordinary "safety razors," care being taken not to scratch or cut the skin with the corners of the blade. When all hair has been removed, the skin is washed with warm tap water and thoroughly dried. Alcohol dressings are not recommended. The area may be covered by a sterile towel.

The operative site is again prepared just before the sterile drapes are applied. It is important that the patient be placed in proper position before this is done.

The skin may again be washed with liberal amounts of soap and water, especial care being devoted to cleansing such areas as under the breasts, the axillae, the umbilicus, and the groins. Following the use of soap and water, the skin is dried, cleansed with ether, and then thoroughly painted with one of the commonly used germicidal solutions. A number of effective germicides are available, but before using any of them, the patient should be questioned carefully as to sensitivity to iodine, organic mercurials, etc

One of the best germicides is a U S P solution of iodine, which should be applied to the skin, allowed to dry for a minute or so, then removed by swabs soaked in 70 per cent alcohol Unless iodine is carefully removed by alcohol, it

may cause disagreeable, even serious, burns. For this reason iodine has been supplanted in many hospitals by the organic mercurials such as Mercresin, Merthiolate, Metaphen, etc. These solutions are left to dry on the skin. Great care should be taken in applying any germicide about the genitalia or perineum, and especially about the eyes.

Aqueous Zephiran and, more recently, synthetic detergents containing G-11 have been introduced as safe and effective bactericidal agents. They are excellent for preoperative preparation of the vagina and perineum when combined with efficient mechanical cleansing with abundant quantities of water.

Fresh traumatic wounds are best prepared for repair by soap and water or by detergents containing G-11.

PREPARATION OF THE SURGEON'S HANDS

Surgeons should exercise the greatest care in avoiding gross contamination of the hands with pathogenic bacteria. When dressing infected wounds, the surgeon should wear gloves and use instruments, changing gloves after each dressing and washing his hands thoroughly when he has finished.

The surgeon should form the habit of washing his hands frequently with soap and water and must use especial care to keep his nails clean. He should also avoid conditions which cause drying and cracking of the skin of the hands.

Mechanical scrubbing with a suitable brush and soap and water probably still is the most effective method for removing bacteria from the skin. A fairly stiff brush is required, but it must not be so stiff as to injure the skin. Orderly and vigorous scrubbing for from seven to ten minutes is required. At the end of the scrub, the soap is rinsed away with tap water and the hands and arms are dried with a sterile towel. If ordinary soap has been used, the arms and hands are immersed in 70 per cent alcohol, then 95 per cent alcohol. Since the 95 per cent alcohol is rapidly removed by evaporation, the sterile gown may be put on without using a towel for drying the hands and arms, a distinct advantage when there are untrained individuals on the surgical team.

Synthetic detergents containing G-11 are now widely used for cleansing the surgeon's hands and arms In many hospitals these agents have replaced soap and water and alcohol. Three minutes' scrubbing with the G-11 detergents was said to be sufficient, but Price apparently has shown this to be inadequate. No alcohol is used after the detergents, so that a fine film of this bactericidal agent is *left on* the skin, with the idea of destroying bacteria which reach the skin surface from the depths of sweat glands and hair follicles.

Between so-called "clean cases," a three-minute scrub with a G-11 soap is generally considered adequate.

SURGICAL INFECTIONS

Space does not allow a full discussion of all the aspects of treatment of postoperative infections, but certain principles are presented. Penicillin and the other antibiotics have brought about a revolution in the prevention and treatment of postoperative infections, but the use of these substances has not altered appreciably the necessity for drainage when pus is discovered. Too much reliance may be placed on the antibiotics rather than on good wound care.

Antibiotics frequently are administered in the treatment of surgical inf without efforts being made to discover the responsible organism and to det the sensitivity of the causative organism to the various antibiotics.

"If we are to give the patient the full benefit of antibiotic therapy, it is nece discover the causative organism and to determine its sensitivity to the available ant This requires close cooperation with a bacteriology laboratory.

"Suspicious exudates should be collected with proper precautions and sent at onc laboratory for appropriate examination. A preliminary report on the causative organ its sensitivity to the antibiotics usually can be given in approximately 24 hours Mixe tions require somewhat longer.

"In acute infections treatment should be instituted at once, using the antibioti seems most likely to succeed Should the laboratory studies indicate that another a or a combination of antibiotics will be more effective, the treatment should be mod indicated." (Meleney)

The routine use of antibiotics in clean surgery is to be avoided. The criminate use of antibiotics, especially penicillin, has led some operators to they can disregard established surgical principles. Nothing is further from the

With penicillin, streptomycin, Chloromycetin, terramycin, bacitracin mycin, polymyxin, and other antibiotics available for the control of infectio should choose the antibiotic for use in the individual case with deliberatio care commensurate with his experience and knowledge of infections.

Little advance has been made in the sterilization of the air in operating Ultraviolet irradiation, successfully employed by Deryl Hart, has not been adopted, probably because of the discomfort imposed upon the operating roo sonnel by the required equipment. The circulation of air cleared of bacteria dust particles by the use of the "Precipitron," or by filtration, as advised by brook and Bourdillion, has better prospects of being generally adopted. B these methods are still relatively elaborate and expensive, but no doubt will b simpler and more reasonable in cost.

The value of these methods of eliminating bacteria from the air in ope rooms apparently is not appreciated by those surgeons who depend upon the biotics to prevent and control wound infections.

SHOCK AND HEMORRHAGE

In 1940 the relation of shock to hemorrhage was so little understood tha often were discussed separately The extensive experimental and clinical in gations on wound shock during World War II have greatly clarified this rel ship. The value of blood pressure readings in estimating the severity of shoc been stressed.

It is now clear that the chief cause of traumatic shock is loss of whole in the zone of injury, and the chief cause of surgical shock is the loss of whole from the site of operation. It seems well established that blood loss must be magnitude of 25 to 40 per cent of the total blood volume to produce severe in the healthy, unanesthetized, young adult However, individuals suffering malnutrition, liver disease, severe infection, dehydration, or old age are mor ceptible to blood loss. That certain anesthetic agents increase the severity of is now generally appreciated. Since the cause of surgical shock is severe bloo the best treatment for surgical shock is prompt restoration of that which has

lost, i.e., whole blood. Although this would seem to be obvious, some surgeons still rely on saline infusions rather than whole blood for shock therapy during operations. Salt solution is better than nothing, *but not much better.*

The best treatment for surgical shock is prevention. This implies the prevention of blood loss by careful hemostasis during operation and the prompt replacement of blood which is unavoidably lost. The first principle, the conservation of blood, is equally as important as the second, but in these days of blood banks, this is too often forgotten.

Before the start of any major operation in which massive blood loss may occur, an accessible vein is cannulated and a slow infusion of 5 per cent dextrose in water is started. Prior to operation the patient's blood is carefully typed and cross-matched with one or more suitable donors or with "bank blood." Blood is given by the indirect or citrate method as blood loss occurs, not after the patient has gone into shock on the operating table or upon return to his bed. If no appreciable blood loss occurs, blood usually should not be given.

Plasma, albumin, and certain plasma substitutes are effective agents in the immediate treatment of surgical shock, if not required in too large quantities (usually above 1,000 c.c.), but they shoud not be considered "blood substitutes"; they contain no red blood cells. *There is no substitute for whole blood* in the treatment of surgical shock.

Intravenous infusion of whole blood is effective in most cases of surgical shock if blood replacement is adequate in amount and rapid, but when this method fails, intra-arterial blood transfusion may prove lifesaving. The bone marrow route may be employed for transfusion in infants and in persons with no accessible suitable veins, but the surgeon rarely will need to use this route if he has learned "to find a vein" in debilitated persons or in those in shock. The femoral vein always can be found and entered, even in patients in deep shock

Shock occurs in combined water and electrolyte loss, such as occurs with persistent vomiting, from pyloric or intestinal obstruction. Although a deficit in plasma volume in these patients commonly is observed, their chief need is the restoration of body fluids by the administration of electrolytes and water. This is accomplished by the intravenous infusions of fairly large quantities of 0.9 per cent sodium chloride solution, usually with some potassium chloride added, or if there is a predominant salt loss, with infusions of 2 per cent sodium chloride solution. Shock in infants suffering from severe diarrhea often is best relieved by infusions of sodium lactate solution. Shock accompanying gastric dilatation following operation generally is not relieved until the stomach is deflated by lavage.

Shock may accompany severe postoperative infection, especially when the peritoneum is diffusely involved. If the picture of shock develops in a patient who recently has had an intestinal resection, one should suspect leakage at the suture line. Shock also may accompany gangrene of the bowel wall, as in volvulus. Although whole blood transfusions are of benefit in these conditions, surgery usually is the only satisfactory definitive treatment.

Concealed, continuing blood loss is commonly the cause of shock which appears early in the postoperative period. If after a major operation, the patient goes into shock four or five hours later, he should be given 500 to 1,000 c.c. whole blood. If the patient's condition does not improve or if the improvement is transient, and the blood volume has not been restored to an effective level, more than likely the

Operator No. 1 draws the blood from the donor. Operator No. 2 cleans the syringes, and Operator No. 3 injects the blood into the vein of the patient. The patient and donor should be lying down and within easy reach of the central table where Operator No. 2 is stationed with basin, syringes, etc. A superficial vein in front of the elbow of both patient and donor is selected. The skin immediately over the prominent vein is cleansed in the usual way and infiltrated with procaine solution, using a small needle. The procedure in entering the vein of the donor and of the patient is similar. A tourniquet of a soft rubber tube is applied to the middle of the upper arm sufficiently tight to retard the venous flow without occluding the artery. After the tourniquet has been on several minutes and the veins have become distended, the needle with its sharp hollow obturator is introduced obliquely through the infiltrated skin into the vein with the bevel of the point downward. After entering the vein, which is easily determined by a few drops of blood coming through the obturator, the obturator is removed and the needle is gently passed about 1 cm. upward in the vein and is held in this position with the left hand. Some operators find it more convenient to have the needle in the donor inserted downward toward the hand, thinking they thus get a better flow of blood. The needle for the patient is always pointed upward. Immediately after removing the obturator, the syringe is attached to the needle and the transfusion may be begun. Up to this point the procedure is identical in both the donor and the patient. After the vein has been entered in the patient, the patient's tourniquet is released and a small amount of saline solution is injected to ascertain whether the needle has been properly placed and that there will be no leakage about the vein. When the needle and syringe are attached or detached, the needle is held between the index and middle fingers of the left hand of the operator, and while the syringes are being changed, the thumb is placed over the end of the needle as a plug to prevent the loss of blood. Operator No 1 draws the syringe full of blood as quickly as possible, disconnects the syringe, places the thumb of the left hand over the base of the needle, and lays the syringe filled with blood on the table within easy reach of Operator No 3, who picks up the syringe, connects it with the needle that is in the vein of the patient, and quickly empties the syringe into the vein. He then detaches the empty syringe, places his thumb on the base of the needle, and passes the syringe to Operator No 2, who carefully discharges any blood left in the syringe into the empty basin and washes it out several times with the sterile distilled water, each time emptying the syringe into the empty basin so that the distilled water is not contaminated with blood Then a small amount of the sodium citrate solution is drawn into the syringe and expelled into the empty basin. This syringe is placed within easy reach of Operator No. 1, who connects it with the needle in the donor's vein and then repeats the operation. If there is any delay, normal saline solution should be slowly injected into the needle until the transfusion is resumed. This may be done both in the donor and the patient. If it is necessary to inject saline solution into the donor, the tourniquet on his arm should be temporarily removed. This is to prevent the blood from clotting and obstructing the needles.

Five hundred cubic centimeters of blood is the usual amount given in a transfusion. While the transfusion is going on, the pulse of both donor and recipient should be taken at intervals of a few minutes After the transfusion has been com-

pleted, the needles are quickly withdrawn, and a small gauze sponge held firmly in place with a strip of adhesive plaster is applied over the site of the puncture in the vein. This gauze sponge should be applied very tightly to prevent any leakage about the vein which would cause a hematoma.

Occasionally it is difficult to find a satisfactory vein in the patient. In such instances the vein must be exposed by an incision and the needle introduced into the vein, or the vein is opened and an intravenous cannula is inserted and tied in place with a ligature (Fig. 23). The intravenous cannulas used have the regular Luer base, and after insertion the same procedure is carried out as when the Unger transfusion needle is used.

Fig. 23.—A ligature has been tied on the distal side of the vein, another ligature placed but not tied on the proximal side, and the vein has been opened with an oblique incision.

FLUID AND SALT REQUIREMENTS IN SURGERY

In ordinary practice the surgeon concerned with problems of fluid and electrolyte requirements is chiefly interested in water, the cations sodium and potassium and the chloride anion. Water makes up about 70 per cent of the total body weight. About 80 per cent of the water of the body is found in the cells, the rest in the extracellular fluids, that is, in the interstitial space and in the blood vessels (Fig. 24). The capillaries are somewhat permeable to water and electrolytes. The cell membrane freely allows passage of water, less so of electrolytes. It is now well known that the sodium and potassium ions readily pass across this membrane.

The osmotic pressure of the body fluids, intra- and extracellular, is maintained by water and electrolyte shifts across these membranes. In Fig. 24 is shown the composition of body fluid components in the normal man. It is seen that the chief cation of the extracellular fluid is sodium and that of the intracellular fluid, potassium. The bulk of the chloride anion is in the extracellular fluid, but recent studies have demonstrated some chloride in the cell. Under normal conditions there is probably not too great transfer of sodium and potassium in and out of the cell, from one body space to another, but in salt depletion sodium can replace, to some extent, potassium loss from the cell.

The shifting extracellular electrolyte, in the normal state, is predominantly sodium chloride. Under ordinary conditions the kidneys adjust excretion of water

and sodium chloride and other solids so accurately to intake that the volume and electrolyte concentration of the extracellular fluid are kept extraordinarily constant, providing the cells with the "internal environment" of Claude Bernard. For body cells to function normally, the volume of extracellular fluid must be kept adequate and the composition and pH must be kept within physiologic limits. Thus, the water balance is regulated nicely in normal persons ingesting food and drinking ordinary amounts of water.

When either water or salt intake is low, as in patients with dysphagia or those so weak they cannot drink adequate amounts of fluid, or when extra renal loss is excessive (as in patients with profuse sweating, excessive vomiting, gastric suction, diarrhea, or bowel fistulas), isotonicity of the body fluids is safeguarded by a de-

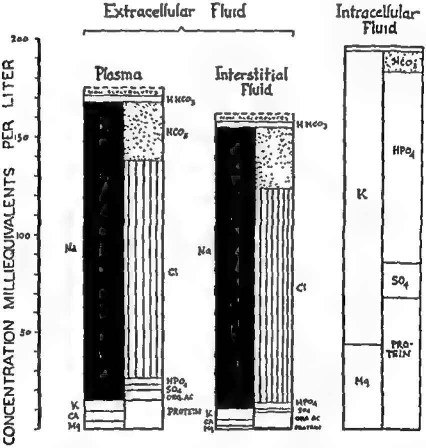

Fig. 24.—Composition of body fluid compartments of normal man. (After Gamble.)

This diagram illustrates that the chief cation inside the cell is potassium, outside the cell, sodium The chloride anion is chiefly in the extracellular fluid The sums of the cations and anions are approximately equal These are shown as milliequivalents, rather than milligrams per 100 c.c Such expression allows quick decision of the state of body fluid equilibrium from chemical data

To convert milligrams per cent to milliequivalents:

$$\text{Na} = \frac{\text{mg } \% \times 10}{23} \times 1 = \text{mEq Na}$$

$$\text{K} = \frac{\text{mg } \% \times 10}{39} \times 1 = \text{mEq K}$$

$$\text{Cl} = \frac{\text{mg } \% \text{ as Cl} \times 10}{35} \times 1 = \text{mEq Cl}$$

$$CO_2 \text{ combining Capacity} = \frac{\text{Vol. } \%}{2.2} = \text{mEq } HCO_3 \text{ per liter}$$

$$\text{Cl from } \% \text{ NaCl} = \frac{\text{Value} \times 10}{58} \times 1 = \text{mEq Cl}$$

crease in either water or salt output (or both) by the kidneys. When renal mechanisms are normal, one may expect to find small urine volumes with water depletion, and low urine salt concentration and excretion with salt depletion. Dehydration is a term that covers both conditions, named according to the initiating causes, primary water depletion and primary salt depletion.

In patients unable to eat or drink, dehydration often is made much worse by the added loss of body water through the skin and respiration (insensible water loss). This extra loss may amount to 700 to 1,000 c.c. of water daily and can be as high as 3 to 5 liters daily if the environmental temperature is much above 100° F.

In primary water depletion the extracellular fluid tends to become hypertonic, although this tendency is compensated for by two mechanisms: water moves from the cell into the extracellular space, and the kidneys diminish their water output to the minimum obtainable by tubular reabsorption. Even though intracellular dehydration is marked, there may be no great change in either the plasma volume or electrolyte concentration. In this condition one may find a small urine volume and normal or increased concentration of plasma, protein, and electrolytes. A marked decrease in water excretion in primary water depletion can occur with very little change in plasma concentration.

Primary water loss is best replaced by the administration of water and no salt, as 5 to 10 per cent dextrose in water. If sweating is responsible for a major portion of the water loss, replacement of salt should be by hypotonic salt solution. A suitable hypotonic salt solution is obtained by combining 0.9 per cent sodium chloride solution and 5 per cent dextrose in water. The urine output is a fairly good guide to the amount of water required and a daily urine output of 800 to 1,000 c.c. is adequate for patients with normal kidney function. Patients with diminished renal concentration power may have to be given much larger amounts of fluid to correct primary water depletion and may have to excrete as much as 2 to 2½ liters of urine daily to clear their blood of nitrogenous waste products. Primary water depletion is not as common as primary salt depletion in ordinary clinical practice, but it occurs in patients with practically complete stricture of the esophagus, in patients who have been in coma for two or three days, and in those who because of extreme weakness are unable to sit up and drink adequate amounts of water. Primary water depletion may be more common in aged, debilitated patients than is generally recognized. These patients have dryness of the mouth and progressive weakness and, if not treated properly, may develop mania or coma. In this state the need of the body is for water; usually very little salt is required.

In primary salt depletion there usually is an abnormal loss of salt from the body with an adequate water intake. This salt loss occurs in excessive vomiting from intestinal obstruction, in continued gastric suction, and in diarrhea or alimentary tract fistulas. In this condition the extracellular fluid tends to become hypotonic. This is especially true in those patients with gastric suction who are allowed large amounts of water to drink. Since the kidneys will not retain water without salt until the salt loss is severe, depletion of body water occurs, even though adequate amounts of water are drunk. The kidneys exert themselves to combat hypotonicity of the body fluids and continue to excrete water but practically no salt, and even when total body salt has been depleted, plasma chloride concentration may remain relatively normal for some time. It falls only when the kidneys can no longer excrete enough extracellular water to compensate for the salt loss. When the plasma chloride concentration does fall, the reduction of body water may

be greatly out of proportion to the decrease in plasma chloride concentration. Pronounced oliguria or even anuria may occur before clinical shock signs are apparent, but the shrinkage of plasma volume may be so great that clinical shock does develop.

The clinical signs of primary salt loss may, therefore, be more important in the diagnosis of this deficit than chemical examination of the blood. When loss of body fluids takes place over a long time, there may be little increase in red cell and plasma protein concentration. If anemia and hypoproteinemia existed before the fluid loss occurred, the change toward concentration may appear as normal and thus mask the true situation

More important than chemical examinations for blood constituents is an intelligent evaluation of the clinical state associated with this deficiency, that is, dehydration and salt loss produced by excessive vomiting, excessive gastric suction and diarrhea. These patients may exhibit all the signs of reduced blood volume such as weakness, tachycardia, poor venous flow, and poor pulse volume. The skin when pinched unfolds slowly, there may be softening of the eyeballs along with other signs of dehydration. In a group of patients with recent ileostomy, studied especially for clinical signs and symptoms associated with progressive primary salt depletion, one of the earliest symptoms noted was the inability to think clearly, often associated with general lassitude · This caused them to forego eating and drinking proper amounts of food and water.

In primary salt depletion, the ionic composition of the plasma reflects changes in chloride and bicarbonate concentration, depending on which type of body fluid is lost in greatest proportion. The loss of gastric juices alone, by vomiting or by suction, usually causes disproportionate removal of the chloride ion. In this state, alkalosis, there is a reduction in plasma chloride below normal, approximately 100 mEq., and elevation of the bicarbonate ion concentrations, usually above 30 mEq. There is usually an accompanying small drop in plasma sodium concentration When bile and pancreatic juices account for the major portion of fluid and salt loss, there is a greater loss of sodium bicarbonate than of sodium chloride. This reduces the plasma bicarbonate to somewhat below 25 mEq. and may slightly increase the plasma chloride concentration, leading to the condition, acidosis If about equal quantities of bicarbonate and chloride are lost from the body, there may be little change in the ratio of concentrations of these ions in the body fluids. Thus, patients with excessive vomiting or continued gastric suction usually show clinical and chemical signs of alkalosis, whereas those who lose fluid and salt because of diarrhea or from intestinal fistulas usually have mild to severe acidosis.

The surgeon should recognize that sodium, not potassium, is the most important cation deficiency in primary salt depletion. This is especially to be emphasized now when most of the attention is being directed toward potassium deficiency in surgical patients.

TREATMENT OF WATER AND SALT DEFICIT IN THE SURGICAL PATIENT

The treatment of the surgical patient with water and salt deficiency is in reality quite simple if attention is devoted to the manner in which the deficiency has been produced As pointed out above, if the deficiency is primarily that of water, such as occurs in those patients unable to drink water or ingest solid food

or after excessive vomiting, the main need for the body is water. Since relatively smaller amounts of salt have been lost, hypotonic solutions of salt are administered or additional water is given as 5 per cent dextrose in water (or amino acid solutions containing little salt) to ensure an adequate daily urine output, approximately 800 to 1,000 c.c. in patients with normal renal function. Salt loss from sweating is corrected by the administration of appropriate amounts of hypotonic solution of salt, 0.45 per cent sodium chloride. The insensible water loss from the lungs is replaced as water alone. This means that the ordinary surgical patient requires about one liter of water per day to correct insensible water loss and approximately one liter of water per day for urine output. The salt loss from sweating is ordinarily so little that no more than 4 to 5 grams of sodium chloride is required daily. Even much less than this may be used early after ordinary operations because in this stress period there is a tendency for retention of body salt and water. If environmental temperature is higher than 100° F., additional water must be given as 5 per cent dextrose in water in amounts sufficient to ensure an adequate daily urine output.

Treatment for primary salt depletion will vary according to the source of extra renal salt loss. In general, the replacement rule is indicated in clinical practice, that is, give back to the body the amounts of water and salt lost When gastric juice is lost by Wangensteen's drainage, the rule of "volume for volume" may be used; for example, if the patient loses 1,200 c.c. of gastric juice per day, this loss may be replaced by the administration of 1,200 c.c. of 0.9 per cent sodium chloride solution. However, if this rule is followed closely, it is likely that more sodium chloride will be given than is actually needed by the patient, because gastric juice often is hypotonic. This is especially true in the early postoperative period when there is a natural tendency for the restriction of the renal excretion of sodium, the result of hyperactivity of the adrenal cortex. In patients with pancreatic or intestinal fistulas, the fluids lost often contain more salt than ordinary body fluids, so these patients lose proportionately much more salt than water. Replacement therapy for this type of patient is best accomplished by hypertonic solutions, 2 to 5 per cent sodium chloride. If isotonic sodium chloride is used for replacement therapy in these patients, the urine output is excessive if the replacement of salt is adequate. In certain ileostomy patients with large losses of body fluid and salt, it was found necessary to give 10 to 12 liters of isotonic saline daily to maintain salt balance, whereas, if 5 per cent sodium chloride was administered, only about 2 liters were required. When isotonic saline alone was used, the urinary output was 8 to 9 liters per day.

There is a common tendency in surgical practice to employ isotonic solutions of sodium chloride (0.9 per cent) in the immediate postoperative period, despite the demonstration by Coller and associates that there is excessive fluid and salt retention when this solution is used. Patients do better in the early postoperative period when replacement therapy consists largely of hypotonic salt solution (0.45 per cent).

In the foregoing, attention has been devoted primarily to replacement therapy for sodium and water deficits. During the past few years it has been established that surgical patients suffer not only sodium chloride loss but also potassium loss. Potassium is the chief cation in intracellular fluid Formerly it was believed that the cell membrane was practically impermeable to potassium and sodium, with very

little, if any, transfer of these cations from one space to the other. Under certain conditions of dehydration and salt deprivation or loss, transfer of some of the cell potassium to the extracellular space may occur, to be replaced under conditions of routine saline therapy by the ingress of sodium from the plasma or interstitial fluids to the cell. As pointed out above, the inordinate loss of body fluids by prolonged vomiting or diarrhea leads to considerable wastage of sodium and chloride. To these losses should be added a considerable loss of potassium. Gastric, biliary, and intestinal fluids may contain large amounts of potassium. When sodium and potassium are lost from the body, the normal kidney tends to conserve sodium by almost complete tubular reabsorption of that ion; the excreted urine contains almost no sodium. Unfortunately, no such renal mechanism acts to conserve body potassium, so even in states of severe potassium depletion this cation continues to be lost in the urine. This loss may be increased by the excessive administration of sodium, by the stress of accidental or surgical trauma, and by the alkalotic state accompanying salt depletion. If replacement therapy ignores this potassium loss, potassium deficiency to some degree will develop.

The signs of extreme potassium deficiency are muscular weakness, paralysis of accessory respiratory muscles, aphonia, and coma. A diagnosis of potassium deficiency is confirmed by characteristic electrocardiographic findings. A serum potassium level of 2.6 mEq. or below is diagnostic. Commonly, the diagnosis of mild to moderate potassium deficiency in the surgical patient is posed upon an intelligent evaluation of the clinical state likely to be associated with such a deficiency. Dehydration and salt loss produced by prolonged gastric suction, excessive vomiting, diarrhea, etc., commonly lead to potassium deficiency. The associated sodium deficiency has most often been corrected by administration of fluids containing only sodium chloride and water. The subsequent dilution of extracellular fluid often accentuates the potassium deficiency. If alkalosis persists in patients after adequate hydration and sodium chloride therapy, potassium deficiency is to be strongly suspected. The diagnosis may be confirmed by analysis of the plasma for potassium, but this requires a flame photometer. The surgeon is advised strongly to suspect potassium deficiency in surgical patients who have suffered excessive losses of body fluids either before or after operation, especially when alkalosis persists after adequate water and sodium chloride replacement.

In severe potassium deficiency it may be necessary to administer rapidly fairly large amounts of potassium. Ringer's solution is inadequate for this therapy because it does not contain enough potassium. The emergency treatment of severe potassium deficiency requires considerable clinical and chemical judgment. If the state of renal function is not known, potassium infusions should be preceded by the intravenous infusion of approximately 800 c.c. of 5 per cent dextrose in water to stimulate urine flow. The important matter is to administer the first few grams of potassium chloride over a period of one to two hours; this usually takes care of the emergency phase of potassium replacement. Four to five grams of potassium chloride is given in one liter of 5 per cent dextrose in water for emergency treatment. After this, potassium replacement may be less rapid, care being taken to administer from 2 to 5 grams of potassium chloride per day, above the calculated daily loss. Once the plasma bicarbonate content has fallen to normal levels and alkalosis is corrected, one can usually conclude the potassium problem has been corrected. Oral administration of potassium chloride should be begun as soon as

possible. Potassium chloride may have to be given in amounts as high as 5 to 10 grams per day orally for some days before potassium depletion is corrected.

If at all possible, potassium chloride *should be administered by the oral route*, the intravenous route being used only when the patient cannot take or retain it when administered orally. Great caution is advised against the possibility that strong solutions of potassium chloride *may be administered rapidly by vein*. Some hospitals supply small vials containing about 40 to 100 c.c. of 10 per cent potassium chloride, to be diluted at the bedside. This practice can be dangerous unless one is confident such concentrated solutions *will not be administered intravenously* without proper dilution.

Water, sodium, and potassium deficits can be prevented by intelligent pre- and postoperative care of the surgical patient. *Gastric and intestinal drainage should* be replaced with adequate amounts of water, sodium, and potassium. Wangensteen drainage of the gastrointestinal tract should be stopped as early as possible in the postoperative period, *and the patient then should be encouraged to eat*.

The recognition of potassium as well as sodium deficiency in surgical patients has led to the development of more balanced solutions for saline infusions in surgical patients. *Accordingly, many investigators now agree that we should largely* abandon the routine use of so-called physiologic saline solution in surgery and use instead a balanced solution containing adequate amounts of potassium and sodium salts. There *is more or less agreement that the sodium chloride content of these* solutions should be about 0.6 per cent with potassium chloride added to make the solution isotonic. The solution advocated by Fox is as follows:

Na	140 mEq.
Cl	103 mEq.
HCO_3	55 mEq.
K	10 mEq
CO	5 mEq
Mg	3 mEq
H_2O	1 liter

The solution accepted for standard use in all Scandinavian countries has the following composition:

Potassium and Sodium Chloride	
KCl	3.8 grams
$Na_2HPO_4 \cdot 2H_2O$	12.0 grams
$NaH_2PO_4 \cdot 2H_2O$	0.3 gram
NaCl	5.4 grams
H_2O to one liter	

Randall has used a balanced solution made up as Na—110, K—30, and Cl—140, all *concentrations* as milliequivalents per liter of water. If these solutions are used for replacement therapy in an intelligent manner, they should help prevent both sodium and potassium deficiency. Nevertheless, when potassium losses are large, the surgeon will *have to add* as much as 2 to 5 grams potassium chloride per liter of 0.6 per cent sodium chloride solution to correct potassium deficiency.

If moderate to extreme acidosis exists, Ringer's lactate solution may be used and given in amounts suggested by Van Slyke to correct the acidosis. It is wise, however, to make a trial of giving only approximately one-half the amounts of Ringer's lactate calculated by the Van Slyke formula and to run a record plasma

rates may occur in elderly individuals, so that a marked depression of respiration results. In such patients the dose should be scaled down or the drug should be eliminated entirely from the preoperative schedule. Children may be given Pentothal Sodium by rectal administration. A dosage of 10 to 20 mg. per pound of body weight will usually result in sleep in fifteen or twenty minutes and last for about two hours. Their condition during this period is usually satisfactory.

Opiates

Morphine is particularly valuable preoperatively. In addition to analgesia, the administration of this drug results in somnolence and euphoria. Morphine is a depressant of the medullary respiratory center, and consequently the dosage must be suited to the individual patient. The dosage must be decreased in elderly or debilitated individuals, or small doses of Demerol may be substituted for morphine. Demerol produces analgesia, sedation, and euphoria, and has some atropine-like action. It also mimics papaverine in relaxing smooth muscle. It is frequently recommended as a sedative in elderly individuals since it is thought not to produce as pronounced respiratory depression as does morphine.

Atropine and Scopolamine

These drugs have two actions which are useful preanesthetically; the first is that of drying the glandular secretions of the respiratory tract. In this respect the action of scopolamine is more pronounced than is that of atropine. Secondly, the parasympathetic autonomic nerves to the heart and respiratory tract are depressed by the action of these drugs, especially by atropine; this decreases the depressant action of the vagus nerves on the heart rate and inhibits the constrictor effect of these nerves on the musculature of the respiratory tract. In addition to this autonomic blocking effect of atropine and scopolamine, there is an effect on the central nervous system. Atropine produces some stimulation of higher cerebral centers and also of the medulla, so that there is a little increase in respiration and metabolism. The action of scopolamine on the central nervous system is one of sedation and the production of drowsiness and retrograde amnesia. An occasional patient may exhibit restlessness or delirium after administration of scopolamine, and this is especially true if it is given in the presence of pain.

Atropine has a wide margin of safety. It causes suppression of sweating so that the skin becomes hot and dry. In children the administration of atropine is sometimes followed by flushing of the skin and elevation of temperature. Ordinarily this is not serious, but in toxic and dehydrated children it may be so.

The time of administration of preanesthetic medication is of great importance; it should be given one hour before the time of operation in order to secure the desired result. Because these drugs have a length of action of two or three hours, it is much better to give them too early than too late. If it is not possible to give them a sufficient length of time before the operation, they should be given intravenously. Atropine or scopolamine and morphine may be combined and when given intravenously the effect will begin in a few minutes. No greater depression results from the intravenous administration of opiates than from their subcutaneous administration; the analgesic effect is somewhat less pronounced.

Premedication is as valuable in children as it is in adults, but careful dosage must be selected in order to achieve the desired effect without causing undue depression. The following doses of morphine and Nembutal are well tolerated by children:

Nembutal (Oral Admin.)		*Morphine* (Hypo.)	
9 mo.–2 years	½ gr.	3-5 years	1/48 gr.
2-4 years	¾ gr.	5-7 years	1/24 gr.
4-7 years	1 gr.	7-10 years	1/18 gr.
7-11 years	1½ gr.	10-12 years	1/12 gr.

INHALATION ANESTHESIA

The adverse effects of inhalation anesthesia are in large measure due to inadequate oxygenation and failure to eliminate carbon dioxide properly. There are grades of anoxia and carbon dioxide retention. Severe anoxia attracts attention and usually is promptly corrected, but the less pronounced states may not be recognized and corrected, with serious results. The deeper the anesthesia, the less chance there is for the protective respiratory reflexes to aid in correcting the difficulty. Cyanosis or the lack of it is not a satisfactory indication as to the state of oxygenation, because cyanosis becomes apparent with different degrees of oxygenation in different individuals. Moreover, obvious cyanosis indicates a marked degree of oxygen desaturation, and a lesser degree of anoxia may cause serious difficulty if allowed to persist. Carbon dioxide is toxic in any except low concentrations. A respiratory center depressed by preoperative sedation plus the anesthetic agent may fail to respond to carbon dioxide concentrations far above the safe level. When high concentrations of oxygen are used, as is the case when such anesthetic agents as ether or cyclopropane are employed, there may be adequate oxygenation even though the respiratory exchange is much reduced. However, under such circumstances carbon dioxide elimination is almost certain to be inadequate. Controlled or manually augmented respiration is necessary to correct this.

Adequate oxygen content in the inspired air and adequate respiratory exchange are necessary. The latter is assured only when there is a completely unobstructed airway. Oxygen absorption and carbon dioxide elimination are seriously interfered with by conditions which are of frequent occurrence during anesthesia, such as relaxation of the tongue or pharyngeal structures, laryngospasm, or a collection of blood or mucus in the respiratory passages. Impairment of the airway also reduces intrapleural pressure and thereby increases the likelihood of pulmonary edema.

Complications of Inhalation Anesthesia

Accidents occurring in connection with inhalation anesthesia usually are due to an overdose of the anesthetic agent or to obstruction along the respiratory tract. A not infrequent cause of respiratory obstruction is the aspiration of vomitus. The vomitus must be removed promptly by aspirating the air passages, and this is most effectively accomplished by bronchoscopy. Acid gastric contents are apt to cause severe pneumonitis if not thoroughly removed. Precautions must be taken to prevent the aspiration of foreign bodies, such as dentures or chewing gum.

Laryngospasm may be initiated by the aspiration of regurgitated material, a not unlikely occurrence when curare is used. Laryngospasm also may occur when

manipulation, such as attempts to insert a tube, are carried out under light anesthesia. Attempts to intubate patients who are under Pentothal anesthesia are especially prone to produce laryngospasm, for the drug is not potent enough to establish an adequate level of anesthesia to withstand such stimulation. In any event, laryngospasm may lead to a very serious degree of anoxia which must be treated by aspirating excess secretions or regurgitated material, then administering oxygen under pressure by a face mask. It may be necessary to intubate the patient to relieve the obstruction and usually it will be necessary to deepen the anesthesia for intubation. Curarization will relax the laryngeal musculature.

Patients who have partial respiratory obstruction due to external pressure on the larynx or trachea will likely become completely obstructed if given a general anesthetic. It is therefore advisable to insert an endotracheal tube, using topical anesthesia, preliminary to the administration of a general anesthetic. Postoperative atelectasis may occur after general, local and regional, or spinal anesthesia. Any one of the following factors or combination of factors may cause atelectasis: depression of or interference with respiration; "splinting" because of painful wounds; depression of the cough reflex from preoperative or postoperative medication, or by the anesthetic; abdominal distention with elevation and fixation of the diaphragm; and interference with the action of the cilia of the respiratory mucosa. The final cause in the majority of cases is bronchial obstruction by plugs of thick mucus.

Aspiration by means of an endotracheal catheter initiates effective coughing and may clear up the atelectasis. Inhalation of a mixture of 5 per cent carbon dioxide and 95 per cent oxygen may be used in conscious patients to produce deep breathing and coughing Thumping the chest wall over the affected area is sometimes effective. However, if these measures are not effective within the first few hours, bronchoscopy with aspiration may be advisable. As a rule, aspiration is not effective after twenty-four hours.

Pneumonitis also may follow the aspiration of foreign material; an example is *the severe pneumonitis which may occur after the aspiration of gastric contents.* Depression of respiration and of the cough reflex sometimes eventuates in pneumonitis or pneumonia, but the initial lesions are areas of lobular atelectasis which coalesce. In the early stages it may not be possible to distinguish, by physical examination or by roentgenograms, pneumonia from lobular atelectasis. In any event, vigorous measures directed toward clearing up the atelectasis may prevent the development of pneumonitis or pneumonia

Reflexes activated by stimulation of the autonomic nervous system may be troublesome during certain operations. Traction on the gall bladder or stimulation of the celiac ganglion may cause a slowing of the pulse and a short transient fall in the systolic blood pressure, resulting in a very narrow pulse pressure. Such effects may be reduced or even prevented by deepening the anesthesia Pressure over the carotid sinus during cervical operations not infrequently produces bradycardia and a precipitate fall in blood pressure This effect may be prevented by administering ether or by procaine block Pentothal and cyclopropane are ineffectual in this respect.

All anesthetic agents may produce cardiac arrhythmias, many of which are of little significance. Significant arrhythmias are often encountered when high concentrations of cyclopropane are used in attempts to secure greater relaxation The administration of Adrenalin during cyclopropane anesthesia will likely result in ven-

tricular fibrillation. Chloroform is known to cause ventricular fibrillation and so does ethyl chloride. A slow, weak, and irregular pulse is produced in certain individuals by intrathoracic manipulation, especially manipulation at the hilum of the lung. When serious arrhythmias occur, the anesthetic should be temporarily discontinued and a high concentration of oxygen must be given. One hundred milligrams of procaine intravenously is sometimes effective. Atropine, 1/100 to 1/150 grain, usually will improve the circulation by increasing the heart rate if that has become abnormally slow. Along with cardiac dysfunction, respiration is affected and must be aided or controlled as seems necessary

Choice of Agent

All anesthetic agents produce some undesirable effects, and each of them has characteristic qualities which should be taken into consideration in connection with specific anesthesia problems. Ether is often described as the safest anesthetic agent, but consideration of the numerous adverse effects indicates this is not always the case. However, ether is the safest anesthetic agent for use by inexpert anesthetists and has a wider range of usefulness than any of the presently employed anesthetic agents The open drop technic of administration may be safer in untrained hands but has disadvantages, often unrecognized. Low-grade anoxia frequently develops, and carbon dioxide retention is not uncommon. When ether is administered by machine with the closed circuit technic, it is possible to control reflexes and obtain adequate relaxation and yet avoid anoxia. Since ether blocks the inhibitory effect of the vagus nerve on the heart, it is well suited for use on patients who have cardiac arrhythmias Ether was formerly considered a poor anesthetic for use in patients with pulmonary infection, because it is irritating and increases the bronchial secretions, but when well administered, ether compares favorably with other inhalation anesthetics in such cases.

Cyclopropane is not irritating and causes no special increase in bronchial secretions, so it is well suited for use in the presence of pulmonary disease. Relaxation may be secured by supplementing cyclopropane with curare or with small amounts of ether. The ether also affords considerable protection against the toxic effects of cyclopropane on the heart. Since cyclopropane is a potent anesthetic agent, it is useful in individuals who are difficult to anesthetize Cylopropane also is suitable for use in many poor-risk patients since it produces comparatively little upset in body metabolism. Cyclopropane is a parasympathomimetic stimulant and is therefore unsuited for use in patients with bronchial asthma Ether, a sympathomimetic stimulant, is the inhalation anesthetic agent of choice in such cases.

Nitrous oxide and ethylene are not sufficiently potent to produce satisfactory anesthesia except by reducing the oxygen content of the mixture below a safe level. Both nitrous oxide and ethylene are useful for supplementing other more potent agents and produce no deleterious effects when so used. When used alone for minor procedures, adequate preliminary medication may make the difference between success and failure. When these gases are mixed with oxygen, the flow must be measured in liters rather than in cubic centimeters to maintain the desired concentration of oxygen, which is being constantly absorbed while the anesthetic gases are inert.

Vinethene and ethyl chloride are useful for the induction of anesthesia in children or for very short procedures. Both of these agents are potent and act rapidly,

	ETHER	VINETHENE	CYCLOPROPANE	NITROUS OXIDE	ETHYLENE
Physical characteristics	Explosive, free of impurities in corked container	Explosive, unstable after opening	Explosive; sweet odor	Not explosive but will burn in an explosive mixture; sweet odor	Explosive; unpleasant odor
Local effect on respiratory tract	Irritation, secretions increased	Irritation; increased mucus	Minimal in anesthetic concentration	No irritation	No irritation
Vomiting center	Stimulation in upper planes of anesthesia	No stimulation	Stimulation	Some stimulation	Some stimulation
Respiration	Stimulation initially, then gradual depression, respiratory arrest with 7 volume per cent	Respiratory arrest before circulatory failure, at 10% by volume, depressed in deep anesthesia	Depression; respiratory arrest before circulatory failure	Slight stimulation	Slight stimulation
Blood pressure	Progressive decrease in deep anesthesia	Depressed in deep anesthesia	No decrease	No effect	No effect
Heart	Arrhythmias not very significant, inhibitory center depressed	No significant change	Rate slowed. Arrhythmias frequent; addition of Adrenalin may cause fibrillation	No effect	No effect
Liver function	Depression, usually temporary, hepatitis has occurred, glycogen depleted	Central necrosis after long or repeated anesthesia	No effect	No effect	No effect
Kidney function	Depressed	No suppression	Temporary suppression	No effect	No effect
Blood	Clotting time decreased 25%; bleeding time unchanged	Bleeding and clotting time unchanged	Bleeding and clotting time unchanged. Dilatation of peripheral arterioles	Clotting time slightly increased	Clotting time decreased. Bleeding time slightly increased
Muscular relaxation	Satisfactory	Not complete	Not complete	No relaxation	No relaxation
Metabolism	Depressed Temperature regulating center depressed Blood sugar increased 200 per cent	Slightly increased blood sugar	Decreased	No effect	Slight effect
Potency	100% anesthetic*, surgical anesthesia with 3½ volume per cent	100% anesthetic; anesthesia with 4% by volume, rapid acting	100% anesthetic, surgical anesthesia with 20-25% by volume	15% anesthetic; 85-90% by volume for anesthesia	15-20% anesthetic; 80-90% by volume for anesthesia

*A 100 per cent anesthetic is one which is potent enough to carry a patient through all the stages of anesthesia to respiratory arrest by its own action.

Fig. 25.

so that a deep level of anesthesia may be reached after only a few deep breaths. This is especially true of ethyl chloride. Ethyl chloride is capable of producing ventricular fibrillation, a serious disadvantage. Muscular tremors and convulsions may occur with Vinethene because of its effect on the spinal cord. Vinethene, if used repeatedly or for prolonged anesthesia, may cause central necrosis of the liver lobules and should not be so used.

Chloroform, because of its low volatility, continues to be used by the open drop technic in hot climates; but, because of the many dangers associated with it, its use should be condemned.

A chart (Fig. 25) shows the different properties and effects of the most frequently used inhalation anesthesia.

ENDOTRACHEAL ANESTHESIA

There are many indications for the use of endotracheal anesthesia and relatively few contraindications. Inexperience and inability on the part of the anesthetist to intubate without undue trauma is a relative contraindication. Inflammatory or neoplastic lesions in the larynx or trachea are contraindications. Tubercle bacilli in the sputum may at times be considered a contraindication since trauma to the laryngeal mucosa might predispose to the development of laryngitis. An aortic aneurism pressing against the trachea is a contraindication because of the danger of rupturing the aneurism. In certain blood dyscrasias with pronounced tendency to bleed, the introduction of an endotracheal tube may cause continued bleeding into the air passages. Intubation of very young infants not infrequently causes laryngeal edema if inexpertly done.

With proper management an endotracheal tube insures an unobstructed airway and provides a greater measure of control of the patient's respiration than one can obtain by any other means. With a suitable tube in place, the anesthetist can avoid anoxia and carbon dioxide retention, and even when the thorax is opened wide he can control the degree of expansion or collapse of the lungs. When used for upper abdominal operations, breathing is quiet and efficient and one obtains greater relaxation than could otherwise be had with the same plane of anesthesia. During certain operations and when certain anesthetic agents are used, the respiration must be augmented or even controlled, and this can be satisfactorily accomplished only by the use of an endotracheal tube. Tubes with inflatable cuffs prevent blood and mucus from entering the bronchial tree and permit aspiration of it.

There are disadvantages associated with the endotracheal technic, but rarely are they sufficiently important to contraindicate its use. Anatomical variations may make intubation difficult, and trauma to the larynx is then likely. Difficult intubation may require several attempts before the tube is successfully introduced, and this results in anoxia. Intubation may be followed by prolonged apnea and rarely by cardiac standstill, presumably the result of inhibitory reflexes initiated through the autonomic nervous system. These reflexes apparently are more likely to occur if intubation is attempted in too light a plane of anesthesia. Benign laryngeal polyps sometimes occur after endotracheal intubation, but the incidence is low. To permit intubation, a deeper plane of anesthesia is necessary at that time than might otherwise be required. Even with a tube in place, kinking of the tube or the collection of blood and mucus in the tube may interfere with respiration and must be avoided.

INTRAVENOUS ANESTHESIA

In this country, at the present time, intravenous anesthesia usually refers to anesthesia from Pentothal Sodium. Intravenous anesthesia is especially acceptable to patients, since it is a most pleasant way of inducing sleep.

Pentothal Sodium has the advantages of ease of administration and simplicity of required apparatus. However, these very advantages have resulted in abuse of the method. When the inhalation agents are used, the establishment of a suitable plane of anesthesia obviously requires some training and skill, but the administration of the anesthetic agent by vein seems a simple matter. However, once the agent enters the blood stream, the anesthetist has much less control of the situation than when inhalation agents are being used. The latter agents are constantly being returned to the lungs by the blood and thus are eliminated from the body quite rapidly. The nonvolatile drugs, such as Pentothal, are disposed of much more slowly. Also the rate of detoxification of Pentothal varies greatly in different patients, depending to a considerable extent on the physical status

Pentothal produces cerebral depression, but reflexes initiated by surgical or other manipulation are not obtunded. Muscle relaxation is not produced, so when this is required, another agent must be used, or a drug such as curare may be used concomitantly to produce the relaxation. After Pentothal induction, ether and oxygen may be used for relaxation

The respiratory center in the medulla is depressed by Pentothal and the minute volume of respiration is decreased, so oxygen should always be given. Proper doses of Pentothal ordinarily have no significant effect on blood pressure or pulse, but large doses of any of the barbiturates are said to depress the vasomotor center. Also a dose of Pentothal which will not produce such an adverse effect in healthy individuals may result in serious circulatory depression in less rugged individuals. Large doses of Pentothal may cause pulmonary edema

While there is no conclusive evidence that Pentothal causes further damage to the liver in patients with hepatic disease, it has been observed that in such cases the period of depression caused by that drug is apt to be prolonged. Pentothal causes a slight rise in blood sugar.

There are a number of contraindications to the use of Pentothal: It must never be given when there is respiratory obstruction, Pentothal results in very quiet respiration so respiratory obstruction may go unnoticed unless it is especially looked for; laryngospasm may occur and may not be detected by casual observation. Where there is danger of the accumulation of blood or mucus in the pharynx, as occurs in operations on the mouth, throat, and nose, Pentothal must not be used without the concomitant use of an endotracheal tube.

Some anesthesiologists consider myocardial disease with a decrease in cardiac output a contraindication to Pentothal. It does not appear to be an acceptable anesthetic in shock cases In shock patients and also in patients with marked anemia, very marked depression may result from its use

Vomiting rarely occurs during Pentothal anesthesia, but regurgitation of stomach contents does occur and is a major hazard.

Careful observation is necessary during the recovery period. "Respiratory collapse" following Pentothal anesthesia is practically always due to respiratory obstruction from such causes as the tongue falling back into the pharynx, or laryngo-

spasm due to an accumulation of secretions in the pharynx. When significant respiratory depression occurs during operation, the patient should not be returned to the ward until it is certain that respiration can be maintained without assistance and without the administration of oxygen.

Sometimes "just a little Pentothal" is requested for short cases involving individuals who are not suitable candidates for the drug. There is no such thing as "a little Pentothal" for anesthesia, for when a sufficient amount has been given to permit any operative procedure, enough has been given to destroy protective reflexes, thereby setting the stage for an accident.

Technic of Administration

Pentothal is best used as a 2½ per cent solution, and a satisfactory technic is to inject 2 c c. of this solution a minute. The respiration is the best indicator of the depth of anesthesia and therefore must be observed with the greatest care. The respirations decrease in rate and amplitude as the depth of anesthesia increases. During the administration of Pentothal, there frequently are periods of apnea; during such periods administration of the drug should be discontinued until it is certain that spontaneous respiration will recur. With these precautions, the injection is continued until the desired level of anesthesia is reached

RESUSCITATION

Anesthesia accidents occur, even under the best of circumstances, but catastrophes usually can be prevented by prompt and efficient action. Regardless of the type of anesthetic accident, the ultimate cause of injury to the patient is anoxia. Practically speaking, there is no oxygen reserve in the body. The ability of the various body cells to withstand anoxia no doubt varies with the attending circumstances, but the cells of the cerebral cortex are always vulnerable.

There are two essentials in resuscitation: oxygenation and the maintenance of an adequate circulation. The most effective means of oxygenating such a patient is the most direct and obvious one, the administration of oxygen through an intratracheal tube. If this is not possible, a tightly fitted mask should be used Intermittent expansion of the lungs may be accomplished by manual compression of the bag or by a machine designed for that purpose. The various respiratory stimulants, such as Coramine, are of little or no value under the conditions now being discussed.

Since promptness in reestablishing oxygenation and an adequate circulation is absolutely essential, suitable equipment must be immediately at hand. Fortunately nothing elaborate is required The anesthetist must be certain the patient has an unobstructed airway. The ordinary rubber airway used in anesthesia is adequate to prevent obstruction by the tongue if a mask is being used. Although an endotracheal tube provides the best means of giving oxygen and prevents the stomach from being distended with gas, it is better to have a live patient with a distended stomach than to risk delay in oxygenating the patient. After the immediate danger has passed, the stomach may be deflated by a gastric tube.

Depression of circulation must also be treated promptly by intravenous infusion of fluids or blood, whichever is indicated. If a vasopressor drug is indicated, 20 mg. of ephedrine intravenously usually will be effective. The interrelationship between the circulation and respiration is such that when there is sudden cessation of one,

the other will be affected within a matter of seconds. The time factor is especially vital when there is cardiac arrest or ventricular fibrillation. As soon as such a diagnosis is made, the anesthetist must begin rhythmic inflation of the lungs with 100 per cent oxygen at a rate of about 20 times a minute. Cardiac massage provides sufficient circulation to maintain viability of the brain cells if the blood is fully saturated with oxygen. When there is doubt that the anesthetist will be able to provide adequate ventilation by manual compression for a long period, a mechanical device for rhythmic compression of the rebreathing bag is advisable.

SPINAL ANESTHESIA

Since the introduction of spinal anesthesia, there have been waves of enthusiasm for or dissatisfaction with the method and marked differences of opinion as to its usefulness. Following the initial enthusiasm for spinal anesthesia, it fell into disfavor because the available drugs were unsafe for such use and also because of a lack of understanding of the physiologic effects produced by blocking the spinal nerves. Since then a number of more satisfactory drugs have been introduced and much has been done toward perfecting the technic of administration of spinal anesthesia. Also a better understanding of the alterations in body physiology has been acquired, and methods have been developed for proper prevention and control of certain of the more important physiologic changes. A better understanding of the problems connected with spinal anesthesia has helped temper enthusiasm for it and dissatisfaction with it.

Pharmacology

Drugs for spinal anesthesia usually are employed as water-soluble hydrochlorides. When these are injected into the subarachnoid space, the more alkaline spinal fluid liberates the free base, the anesthetic agent. Some failures of spinal anesthesia are reportedly due to the fact that the pH of the spinal fluid is such that the anesthetic substance is not released When a drug is injected intrathecally, its concentration rapidly diminishes, first by dilution and then as a result of fixation by nerve tissue or through vascular absorption With the onset of anesthesia, the sensations of light touch, pain, temperature, pressure sense, and motor function are blocked in that order, and functions return in the reverse order. The basis for this apparently is that the drug acts first on unmyelinated nerve fibers The spinal nerves, the nerve tracts in the spinal cord, and the sympathetic fibers apparently are all affected. Part of the fall in blood pressure at the onset of spinal anesthesia is due to interference with the vasoconstricting action of the sympathetic nerves. As vasodilatation occurs in the area of anesthesia, compensatory vasoconstriction takes place in the unaffected areas and this tends to stabilize the blood pressure. Low spinal anesthesia results in little blood pressure change in normal individuals because of this compensatory action, but the higher the level of anesthesia, the smaller is the area of the body in which compensatory vasoconstriction can occur and the greater is the tendency for the blood pressure to fall When the sympathetic cardioaccelerator nerves in the thoracic portion of the cord are blocked, the parasympathetic nerve supply to the heart functions unopposed, and this supposedly accounts for the slow pulse observed in patients with high spinal anesthesia

Indications

Success with this method of anesthesia depends largely on the proper selection of cases. Spinal anesthesia is said to be suitable for all operations below the diaphragm, but this should not be interpreted as meaning it is always the anesthesia of choice for operations in this area. Spinal anesthesia does provide excellent operating conditions because it gives such complete skeletal muscle relaxation, and when ease of exposure is of prime importance, spinal anesthesia merits consideration. Along with skeletal muscle relaxation, there is contraction of the smooth muscle of the bowel wall, and this also aids the surgeon in gaining an adequate exposure. Spinal anesthesia, essentially a form of regional anesthesia, interferes less with the body physiology than do any of the general anesthetics. It is, therefore, suitable for use in patients with liver or renal disease, as well as in those with diabetes and other metabolic disorders Whether or not spinal anesthesia is used for operations in the upper abdomen should depend primarily on the ability of the anesthetist to institute and maintain an adequate level of anesthesia and at the same time keep the patient's circulation and respiration functioning satisfactorily. An adequate level of anesthesia is more easily obtained and the incidence of untoward reactions is less when spinal anesthesia is used for operations in the lower abdomen and pelvis and upon the lower extremities.

Spinal anesthesia has been recommended for patients with acute upper respiratory infections in whom operation is urgently required. Statistics indicate, however, that pulmonary complications occur just as frequently after spinal anesthesia as following general anesthesia.

Contraindications

Infection at the site for spinal puncture is an absolute contraindication to the use of spinal anesthesia. Diseases of the central nervous system, including the cord changes incident to pernicious anemia, contraindicate spinal anesthesia Patients in cardiac decompensation may not have the reserve to withstand marked changes in blood pressure, and a marked drop in blood pressure interferes with filling of the coronary arteries, rendering patients with coronary artery disease unsuitable for high spinal anesthesia. Spinal anesthesia is not suitable for patients in shock or for individuals suffering from a significant degree of anemia. Patients with either of these conditions are particularly apt to show a marked fall in blood pressure under spinal anesthesia, and such hypotension is often difficult to correct. Extreme degrees of hypotension or hypertension are contraindications to spinal anesthesia. Patients with marked hypertension are particularly liable to exhibit sudden and alarming falls in blood pressure. Debilitated or cachectic individuals usually do not tolerate spinal anesthesia well.

High spinal anesthesia generally is not suitable for use in "poor-risk" cases, for the stress imposed on the circulation requires a certain degree of sthenia.

Inexperience of the anesthetist and lack of facilities to combat the immediate complications of spinal anesthesia should contraindicate its use. Necessary facilities include means for the administration of oxygen under positive pressure if it becomes necessary to take over the patient's respiration, adequate provision for giving intravenous fluids, including blood, equipment for tracheal intubation, and certain vasopressor drugs

d. Rapid infusion of fluids or blood.
e. Raise or lower head of operating table, depending on baricity of the drug, to prevent further ascent.

LOCAL ANESTHESIA

When local anesthesia is used under suitable circumstances, it produces fewer disturbances in body physiology than any type of anesthesia. Local anesthesia is therefore especially useful in poor-risk and elderly patients. Local anesthesia is made far more effective by proper premedication Additional sedation can be rapidly achieved, when necessary, by the intravenous administration of one of the soluble barbiturates or by the intravenous injection of a combination of scopolamine and morphine in the ratio of 1 to 25; for instance, scopolamine gr. 1/100 and morphine gr. 1/4. A local anesthetic may be used to supplement very light general anesthesia. An abdominal block, for instance, is adequate until the peritoneal cavity is entered and traction is made on the viscera; at this point the traction pain, which is transmitted by the sympathetic nervous system, can be obtunded by producing light general anesthesia with an agent such as cyclopropane or by the intravenous administration of a small amount of Pentothal Sodium.

Conduction or regional anesthesia is a most satisfactory technic for inducing local anesthesia in many areas. In other areas, a combination of conduction and local infiltration anesthesia gives more reliable results.

Toxicology

All drugs used for local anesthesia are toxic, and complications may be expected to follow their use unless proper precautions are taken. The initial effect of these drugs on the central nervous system is stimulation, producing convulsions if a sufficient dosage is assimilated. This is followed by depression and then collapse. The signs and symptoms of reaction to a local anesthetic drug are nervousness, apprehension, pallor, sweating, rapid pulse becoming weak, irregular and shallow respiration, convulsions, coma, and finally arrest of respiration and circulation Important factors in the production of such a reaction are (1) the quantity of drug injected, (2) the rate of absorption of the drug, and (3) the rate of detoxification. Procaine, for instance, is safer than cocaine, largely because it is more rapidly metabolized by the body. The ratio of toxicity of some of the commonly used drugs is as follows:

Procaine	1	Nupercaine	20
Metycaine	3	Cocaine	4
Pontocaine	10	Anesthesin	½

These drugs are not used in the same per cent concentration, so that the corrected toxicity is not the same as that given above However, procaine is generally considered the safest drug for use in the production of local anesthesia It is unsafe to use more than 1 gram of procaine for any one procedure. The dosage can be kept within proper limits by using solutions of proper strength; a 2 per cent solution of procaine is necessary only for penetration of large nerve trunks, such as those involved in a brachial plexus or caudal block, for almost all other blocks, a 1 per cent solution suffices, and when used for field block or local infiltration, a ½ or ¼ per cent solution is adequate. In elderly or debilitated individuals and in children, the concentration and dosage of the drug should be decreased. The rate of absorp-

tion of the drug may be appreciably slowed by adding a vasoconstrictor substance, usually Adrenalin. When Adrenalin (epinephrine) is used, it is added in amount sufficient to give a concentration of that substance of not more than 1 part in 200,000 parts of the solution. This strength gives adequate vasoconstriction, and the use of a larger quantity of Adrenalin may give a disagreeable reaction. Incidentally, the local anesthetic agent is frequently blamed for such reactions. The addition of a vasoconstrictor substance not only slows absorption but also prolongs the period of anesthesia. During the induction of local anesthesia, special care must be taken *to avoid the intravascular injection of the drug;* for the introduction of as little as 100 mg. of procaine into the blood stream may result in convulsions. In caudal or other epidural blocks and in paravertebral or cervical blocks, it is possible to deposit the drug in the subarachnoid space, especially since this space may extend along the nerve sheaths for an appreciable distance outside the vertebral canal.

A barbiturate with moderately prolonged action, Nembutal for example, should be given an hour before injection of the local anesthetic is begun. This usually prevents a reaction from the anesthetic drug.

Treatment of Complications

Patients who are being operated upon under local anesthesia should be carefully *watched for evidence of reaction. Most reactions can* be *successfully handled,* but only if the necessary items of equipment are immediately available. The most important of these is a rapid-acting soluble barbiturate of which Pentothal is the most satisfactory, since it acts and is eliminated most rapidly. If, when the first symptoms are observed, a small amount is given intravenously, one can prevent further development of the reaction. If convulsions do occur, a few cubic centimeters of Pentothal will control them. Oxygen should also be given, but it is useless to attempt to do this until the convulsions have been controlled Following major reactions the blood pressure falls, but this may be corrected by the prompt administration of fluids by vein. Unless these simple agents are immediately available, the time taken to assemble and prepare them will likely result in the death of the patient should a major reaction occur.

CURARE

Curare may be used supplementary to certain anesthetic agents such as Pentothal to give muscle relaxation. It is also used to supplement small amounts of such anesthetic agents as ether and cyclopropane. Adequate relaxation may thus be obtained without exposing the patient to the deleterious and disagreeable effects which so often follow the use of larger quantities of these agents. Curare is a potent drug and must not be employed by individuals inadequately trained in anesthesia. In this connection it is well to remember that curare originally was used to kill animals by placing a small amount of it on the tip of an arrow. Standardization and purification have not removed the action which made this possible.

Nervous System

While the exact mode of action of curare on the central nervous system has not been determined, it is obvious that it plays no *part in narcotizing* the patient. It acts peripherally as an autonomic blocking agent and it is thought that the fall

in blood pressure that occasionally occurs following the use of curare is due to blocking of the sympathetic ganglia It has been suggested that curare be used to block carotid sinus, vagal and celiac ganglion reflexes.

Cardiovascular System

Curare has no direct action on the myocardium. The fall in blood pressure which sometimes occurs during the use of curare is thought to be caused by the following factors: blocking of the sympathetic ganglia, relaxation of the skeletal musculature with loss of support for the vascular bed, and the release of histamine. The release of histamine has been demonstrated following the administration of curare.

Respiratory System

Weakness, even complete paralysis of the muscles of respiration, occurs as a result of the peripheral action of curare. In the dosage used in connection with anesthesia, curare has no effect on the respiratory center, but when used in amounts sufficient to give adequate relaxation, it inevitably causes a decreased respiratory exchange. Bronchospasm, which occasionally occurs during light anesthesia, is most likely caused by the release of histamine through the action of curare.

Muscular Relaxation

Curare produces muscular relaxation by blocking the nervous impulse at the neuromuscular junction. The small muscles of the head and neck are first affected, then, with increase in dosage, the muscles of the trunk and extremities are involved. The diaphragm fortunately is the last muscle affected.

Curare produces no significant effects on patients other than those described and is suitable for use in supplementing anesthesia in poor-risk patients. It does not enter the fetal circulation and therefore may be safely used in connection with obstetrical anesthesia. It has no effect on smooth muscle.

Myasthenia gravis, obstruction of the respiratory tract, and *inability to gain control of the patient's respirations by intubation* are contraindications to the use of curare.

Technic of Administration

The average initial dose of curare is about 2 c.c., which contains 6 mg. or 40 units of d-tubocurarine. This amount of the drug, administered intravenously, after light general anesthesia is attained, may give adequate muscle relaxation, but the dosage must vary with the individual patient. The effect is noted within about two minutes, and within three or four minutes maximal relaxation will have occurred. Subsequent doses of 0.5 to 1 c.c can be given to secure and maintain the desired relaxation. There is always some degree of respiratory depression, but this usually disappears within approximately ten minutes, while muscular relaxation ordinarily lasts for twenty to thirty minutes. Since there is some cumulative effect with curare, subsequent doses should not be as large as the original dose. Because patients under the influence of curare are unable to make adequate respiratory excursions, they must have respiratory assistance from the anesthetist. Also, an endotracheal tube is usually necessary and if not inserted must be immediately available. The difficulties reported in connection with the use of curare are probably due to inadequate

respiratory exchange, causing anoxia and retention of carbon dioxide. Prolonged partial asphyxia may produce irreversible changes in the respiratory mechanism Inadequate respiratory excursions also may result in atelectasis of portions of the lung. As mentioned previously, the absence of cyanosis does not necessarily mean there is adequate respiratory exchange.

Antidotes

It is imperative to administer oxygen by mask or preferably through an endotracheal tube along with manual compression of the rebreathing bag until the patient resumes normal respirations. Prostigmin is pharmacologically antagonistic to curare and may be of some benefit when given in 1 or 2 c.c. doses Atropine should be given with the Prostigmin.

INTRAVENOUS PROCAINE

Procaine, administered intravenously, has been used for general anesthesia and sometimes to supplement other anesthetic agents, but it is most useful for the relief of severe pain and in the treatment of certain allergic manifestations. The indications for the intravenous administration of procaine still are not well defined. It was first used to relieve the intense itching often associated with jaundice. Procaine frequently is given intravenously to correct cardiac arrhythmias, particularly those which develop during intrathoracic operations It is also used as a prophylactic measure to prevent cardiac arrhythmias from occurring in the course of certain surgical procedures, especially those performed near the heart Pharmacologically, procaine apparently acts as an antagonist of acetylcholine, producing a depressant effect at the myoneural junction Also it is thought that it may potentiate the action of Adrenalin when used in the treatment of serum sickness.

Method of Administration

The patient should be given a barbiturate an hour before the intravenous administration of procaine. For therapeutic purposes, procaine is given intravenously in 0.1 or 0.2 per cent solutions mixed with normal saline or dextrose solution. The mixture should be given very slowly for the first ten or fifteen minutes, and the patient should be carefully observed for the possibility of an adverse procaine reaction. The initial manifestations of a procaine reaction are: cerebral stimulation with nervousness, apprehension, pallor, sweating, and irregular respirations, followed by depression and collapse. Convulsions may occur during the period of stimulation. Allergic reactions with an asthmatic type of breathing also are said to occur. Rapid acting barbiturates such as Pentothal are antidotes for procaine and should be available for immediate use. Oxygen also should be immediately available and should be given. If asthma develops, Adrenalin should be given for its relief. After it has been determined that the patient has no undue sensitivity to procaine, the rate of injection may be speeded up so that the administration is completed within an hour. Four milligrams of procaine per kilogram of body weight, every twenty minutes, appear to be the optimum dose. A convenient method is to mix 1 gram of procaine in 0.1 or 0.2 per cent solution, giving the entire amount to the patient at the recommended rate, if necessary for relief.

CHOICE OF ANESTHESIA FOR SPECIFIC OPERATIONS

Anesthesia in Thoracic Surgery

The majority of anesthetic agents and many anesthesia technics have been used for thoracic operations. For operations upon the thoracic wall, including thoracoplasties, various forms of local anesthesia or combinations of local anesthesia with light general anesthesia may be employed, but if there is any likelihood of interference with respiratory function during such operations, general anesthesia should be administered, using the endotracheal technic. Patients who are to have thoracic operations often have impaired respiratory physiology, making it especially important that means for providing adequate ventilation be immediately available. Even in patients with essentially normal pulmonary function, wide opening of the chest causes reduction in lung volume, paradoxical motion, and interference with the flow of blood to the heart. Ventilation and oxygenation are thereby seriously impaired.

With the pleura open, the exposed lung collapses, and the mediastinum shifts toward the opposite side, partially collapsing the opposite lung. This sudden deflation of the lungs reflexly produces more vigorous respiratory efforts, and if the mediastinum is normally mobile, these exaggerated respiratory efforts result in so-called mediastinal flutter with paradoxical respirations. In paradoxical respiration, during expiration, a portion of the air passes from the protected lung to the exposed lung, then is drawn back into the protected lung during inspiration This leads to anoxemia and retention of carbon dioxide The anoxemia stimulates the carotid body, and the accumulation of carbon dioxide stimulates the respiratory center in the medulla. With an intratracheal tube in place, one can readily prevent pulmonary collapse and paradoxical movement by raising the intrabronchial pressure to, or a little above, atmospheric pressure A mixture of an anesthetic gas with a high concentration of oxygen may be used to distend the lung, thus preventing anoxia and avoiding the reflex stimulation which results from pulmonary collapse. When ventilation is inadequate, the administration of oxygen will prevent cyanosis, but carbon dioxide will not be properly eliminated and this will result in a reduction of the alkali reserve By assisting respiration, excess carbon dioxide may be eliminated An intratracheal tube permits frequent aspiration of the tracheobronchial tree, which is important in all thoracic operations, and altogether necessary in operations for pulmonary abscess, pulmonary tuberculosis, and bronchiectasis. The evacuation of pus frequently is a major problem during thoracic operations. Preoperative postural drainage is of some benefit, but it is essential that purulent secretions be aspirated frequently, so the patient should be placed in such a position on the operating table as to facilitate drainage into the trachea where the suction tube can pick it up

Cardiac arrhythmias often occur during intrathoracic operations, especially when the hilum of the lung is manipulated. Bradycardia with a normal rhythm also may develop under such circumstances The intravenous administration of atropine usually will correct the bradycardia, and the intravenous administration of 100 mg of procaine is recommended for the correction of the cardiac arrhythmias

Ether is probably used more than any other agent for thoracic anesthesia and is generally satisfactory However, it tends to cause an increase in the rate and

depth of the respirations, and this may be undesirable in some cases. Cyclopropane given with ether promotes quiet respirations and should be used under certain circumstances.

Anesthesia in Patients With Heart Disease

Before operation, patients with symptoms or signs suggesting heart disease should undergo complete studies, including a careful and complete physical examination, x-ray and fluoroscopic examinations, and electrocardiograms. These studies are important and may reveal significant findings, but the functional capacity of the heart, or the cardiac reserve, is of the greatest importance. For this reason a carefully taken history is essential, for from the history and from certain exercise tolerance tests one obtains the most reliable evidence regarding the cardiac reserve. Heart murmurs and certain abnormalities revealed by laboratory studies often are of no special importance in connection with the administration of anesthesia, but the functional capacity of the heart is always of the greatest importance.

Patients in cardiac failure and those with recent coronary artery occlusion or severe angina pectoris are especially poor risks for any type of general anesthesia and should be submitted to operations requiring such anesthesia only when surgery appears to be absolutely necessary When operation is required on patients in cardiac failure, they should be adequately digitalized preoperatively. Digitalization by the intravenous route may be accomplished so rapidly it rarely is necessary to proceed with surgery before this therapeutic effect has been obtained.

Anoxia in patients with heart disease almost inevitably leads to disaster, so it is essential that such patients be kept well oxygenated during the induction period. The induction should, therefore, be smooth and quiet Once an adequate level of anesthesia is established, the danger from anoxia is reduced, but an abundant supply of oxygen must be administered continuously. This should be kept in mind when choosing anesthetic agents for patients with heart disease. All of the agents presently used in general anesthesia have some adverse effect on the heart Cyclopropane produces more significant arrhythmias than other agents, but these may be avoided by using moderate levels of anesthesia and by combining cyclopropane with other agents. Curare used with light cyclopropane anesthesia provides the desired relaxation. The addition of a small amount of ether also promotes relaxation and helps prevent the development of arrhythmias during cyclopropane anesthesia. Induction of anesthesia with cyclopropane is not particularly objectionable to the patient, since a high percentage of oxygen may be given continuously and there is a minimal period of excitement. However, in patients with significant arrhythmias, cyclopropane probably should be avoided. An ether-oxygen mixture is satisfactory for cardiac patients once anesthesia has been established, but a less objectionable agent should be used for induction. Ether appears to have no significant adverse effect on preexisting arrhythmias Nitrous oxide and ethylene are not effective when used with high concentrations of oxygen and therefore are not suitable for use in cardiac patients except to supplement other anesthetic agents. When cardiac failure already exists, Pentothal may increase the failure, but in other forms of heart disease it apparently is well tolerated. However, high concentrations of oxygen must always be given to cardiac patients along with *Pentothal.*

Spinal anesthesia rarely should be used in patients with seriously impaired cardiac function, especially those with coronary artery disease, for this type of

anesthesia often causes some circulatory instability, and a good cardiac reserve is necessary to compensate for this. However, spinal anesthesia may be used when only a low level of anesthesia is required, as in operations on the lower genitourinary tract and in leg amputations. In such cases there should be no pronounced changes in blood pressure. Spinal anesthesia is recommended by some in patients with cardiac decompensation, but a well-conducted inhalation anesthesia gives better control of the patient.

Local anesthesia may be used to excellent advantage in patients with heart disease when the anatomical location is suitable. Apprehension and stress can be largely avoided by proper preoperative sedation. Occasionally it is advisable to give Nembutal Sodium or a combination of morphine and scopolamine by vein during an operation.

Anesthesia in Diabetes Mellitus

Preliminary to elective operations, patients with diabetes should have their sugar metabolism controlled, and dehydration or acidosis must be corrected. During this preliminary period it is essential that there be an adequate caloric intake. In emergencies, dextrose solution containing insulin is given intravenously.

When feasible, local or spinal anesthesia serve the purpose well, for they do not increase the metabolic imbalance. General anesthesia is not necessarily contraindicated in patients with diabetes, but it is important that the anesthetic agent or agents be chosen with care. Certain of the agents commonly used to induce general anesthesia have little or no adverse effect on sugar metabolism, on the acid-base balance, or on the liver and its glycogen content. Cyclopropane and Pentothal are in this group and may therefore be used in diabetics with only moderate risk. Ether, on the other hand, produces a number of undesirable effects and should be used with great care, especially in individuals who have not had careful preoperative preparation.

Anesthesia in Thyroid Surgery

Preliminary medication is of great importance in patients with hyperthyroidism, for such patients require larger dosage for sedation than do individuals with normal metabolic rates. When local anesthesia is to be used, the sedation should be sufficient to render the patient drowsy and somewhat euphoric. If a thyrotoxic patient arrives in the operating room inadequately sedated for operation under local anesthesia, a soluble, short-acting barbiturate or morphine and scopolamine may be given by vein Adequate sedation also is a necessary preliminary to general anesthesia in these patients

Goiter patients with tracheal compression present especially difficult problems. When such patients are given general anesthesia, the accessory respiratory muscles relax, and complete tracheal obstruction occurs Unless the anesthetist is very expert in intubation, the patient may die of asphyxia. It is wiser, therefore, to apply a topical anesthetic to the throat and larynx, then pass an endotracheal tube preliminary to the administration of the general anesthetic.

Ether is often used for thyroidectomy, but may be undesirable in thyrotoxic patients because it produces considerable depletion of the liver glycogen. Cyclo-

propane has no such effect and is consequently a safer anesthetic agent in patients with hyperthyroidism. Pentothal and nitrous oxide, supplemented by small amounts of curare, may provide satisfactory anesthesia, but traction on the trachea is apt to produce laryngospasm, so an intratracheal tube should be placed when this combination is to be employed.

Local infiltration or cervical plexus block, alone or in combination, provide satisfactory anesthesia for thyroid surgery. In patients with hyperthyroidism, the anesthetic solution should contain no Adrenalin. Cobefrine in 1:40,000 or 1:80,000 dilution may be used as a vasoconstrictor.

Anesthesia for Neurosurgical Operations

Local anesthesia is useful in neurosurgery, particularly when combined with adequate sedation. However, positioning the patient so that the anesthetist is unable to insert an intratracheal tube and then supplementing the inadequate local anesthesia with Pentothal is to be condemned.

For intracranial operations, quiet unobstructed respiration is essential. Anoxia causes cerebral congestion, and carbon dioxide retention produces dilation of the pial vessels. Properly administered endotracheal anesthesia obviates these difficulties, but the position of the patient occasionally causes kinking of the endotracheal tube, and this must be guarded against. Plastic endotracheal tubes, or those with embedded wire spirals prevent this difficulty. When patients are to be placed in the prone position as for operations upon the spinal cord, the endotracheal technic should always be used. Endotracheal anesthesia also is suitable for operations for ruptured intervertebral discs, but spinal anesthesia also is satisfactory here Fifty milligrams of procaine and 10 mg. of Pontocaine will provide sufficiently long anesthesia for most of these cases.

Anesthesia for Cleft Palate and Harelip Operations

For such operations, the following routine is satisfactory: For induction give Vinethene, then switch to ether until the patient is sufficiently relaxed for atraumatic intubation Following intubation, anesthesia may be maintained by the Ayre technic or with a nonrebreathing valve. Deep anesthesia is not necessary, but a level adequate to assure quiet and even respiration without "bucking" on the endotracheal tube is essential. The head of the operating table should be slightly lowered, and the throat should be packed with moist gauze to insure against blood or mucus entering the trachea Anesthesia by this technic has significantly reduced the operative mortality in these cases. The insufflation technic is unsatisfactory since it does not assure adequate oxygenation. There is always a considerable amount of blood and mucus in the air passages with some degree of obstruction to the airway, which results in inadequate elimination of carbon dioxide. Also the increased respirations cause increased bleeding. Most operators find an oral endotracheal tube less in the way than a nasotracheal tube. The right-angled metal connector should be firmly in the corner of the mouth, well out of the surgeon's way.

Anesthesia for Maxillofacial Surgery

Endotracheal anesthesia, with either orotracheal or nasotracheal tube, is satisfactory for this type of surgery. Pentothal and nitrous oxide are desirable for most

cases because the electrocautery is so frequently employed in this area. Pentothal anesthesia without an intratracheal tube, always dangerous, is especially dangerous for surgery in this area. The collection of blood and mucus in the air passages along with the depressed breathing caused by Pentothal is likely to lead to disaster.

Anesthesia for Orthopedic Surgery

Most orthopedic operations present no special anesthetic problems. Pentothal and nitrous oxide provide adequate anesthesia in the majority, and in those individuals who are difficult to control with a reasonable amount of Pentothal, a more potent agent such as cyclopropane may be used to advantage. Ether and oxygen anesthesia also is satisfactory. Elderly patients who are to have reduction of hip fractures require special consideration Unless there are contraindications, a small amount of Pentothal supplemented by a 50-50 mixture of nitrous oxide and oxygen usually proves satisfactory.

Anesthesia for Urologic Surgery

Many patients on whom urologic procedures are to be performed are elderly and in an age group where cardiovascular disease is common. Many of them will have some degree of renal dysfunction and this must be taken into account in selecting the anesthetic. In addition, the frequent use of various electrical appliances in urologic surgery eliminates the use of explosive agents.

Spinal anesthesia is especially suitable for many urologic procedures, since only a low level of anesthesia is so often required. A moderate dose of the anesthetic drug and a small volume should be used to insure a low level of anesthesia.

Many patients may be given Pentothal combined with a mixture of equal parts of nitrous oxide and oxygen. Urologists should be aware of the advantages of local infiltration anesthesia combined with regional anesthesia, since so many of their patients are poor operative risks. For example, in renal and ureteral lesions, local injection of procaine solution into the wound area, and paravertebral block of the tenth, eleventh, and twelfth thoracic and first lumbar segments provides excellent anesthesia with fewer hazards than either general or spinal anesthesia.

Operations on Patients With Pulmonary Disease

Patients with extensive pulmonary disease are difficult anesthesia problems because of their lowered vital capacity as well as the presence of excessive secretions in the air passages. Patients with marked reduction in vital capacity should be given an anesthetic which is effective when combined with a high percentage of oxygen. Ether and cyclopropane both meet this requirement, but ether increases bronchial secretions and is often undesirable for this reason. Local infiltration and regional block combined with an inhalation anesthetic often prove satisfactory in such cases. When there is a significant degree of emphysema, induction with an inhalation agent is prolonged and so is the time required for reaction Under such circumstances one may produce a "nitrogen blow-off" by administering a large volume of oxygen By this means oxygen is made to displace a large part of the nitrogen in the pulmonary alveoli and in the body tissues Oxygen combined with an anesthetic agent now is more readily absorbed

Operations on Patients in Shock

It is generally agreed that, whenever possible, operation should be deferred until shock has been adequately treated, but shock often cannot be controlled in the presence of continued hemorrhage. Under such circumstances, immediate surgery may give patients their only chance of survival. In these cases the prompt administration of blood or plasma (preferably blood) is essential. Exposure of a vein and insertion of a cannula often is required to establish means of giving adequate amounts of blood at a sufficiently rapid rate. When operation is to be done in an area anatomically suitable, local infiltration and regional block anesthesia should be used. Oxygen should be given to such patients in high concentration so as to permit complete saturation of the blood.

If general anesthesia is necessary, cyclopropane appears to be best tolerated. It may be necessary to supplement this with curare or a little ether for relaxation. Experimental and clinical evidence indicates that Pentothal and ether are less well tolerated.

Spinal anesthesia should not be used on patients in shock.

Anesthesia for Operation on Patients With Intestinal Obstruction and Pronounced Distention

In patients with intestinal obstruction, a Levine tube must be used to empty the stomach and the proximal jejunum before anesthesia is begun, otherwise vomiting may occur with aspiration of the vomitus into the air passages. This is especially apt to happen if curare is used, for it relaxes both the diaphragmatic pinchcock and the pharyngeal constrictors and allows the gastric contents to enter the larynx. These are seriously ill patients, so a well-conducted anesthesia is essential. On the other hand, the surgeon faces difficult operative conditions, requiring good relaxation. Endotracheal anesthesia provides the best control for this situation. The anesthetic agent or agents used must be decided upon in each individual case on the basis of the associated circumstances.

Spinal anesthesia frequently is recommended, and in patients with early obstruction it may be the anesthetic of choice. In late obstruction the blood volume is reduced, so the vasodilatation which accompanies spinal anesthesia is apt to produce circulatory collapse. Also the level of spinal anesthesia is difficult to control in these cases. Cases have been reported in which it was thought that rupture of a gangrenous gut resulted from the increased contraction caused by the spinal anesthesia.

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CHAPTER 7

COLLATERAL CIRCULATION; EXPOSURE AND LIGATION OF ARTERIES

I. A. Bigger

One of the chief indications for ligation of major blood vessels in preantiseptic days was secondary hemorrhage following suppuration. This indication is infrequent now, so the elaborate operations that were formerly devised for ligation of almost every artery in the body are largely unnecessary. However, occlusion of such large arteries as the carotids, subclavians, iliacs, and femorals may be indicated in the treatment of aneurisms, or for the control of hemorrhage, the result of injury, infection, or neoplasm. Certain of these vessels also may be ligated during, or preliminary to, major amputations. The large veins, especially those of the lower half of the body, including the inferior vena cava, are often ligated as a means of preventing pulmonary embolism, after the development of venous thrombosis, or, under certain circumstances, as a prophylactic measure.

There are certain general principles more or less applicable to the occlusion of all large arteries. If there is a choice as to the site of ligation, that area should be chosen which promises the greatest chance for the development of an adequate collateral circulation. For example, if there is a choice between ligation of the common femoral and external iliac arteries, the latter site is preferable because the inferior epigastric artery is preserved as an important collateral channel. In general, the more central the obstruction of large vessels, the greater the chance for the development of an adequate collateral circulation, but there are numerous exceptions to this rule. Such an exception is found in connection with the femoral arteries. The superficial femoral artery has an excellent collateral bed, whereas the common femoral has a poor collateral. To choose the most desirable site for ligation it is necessary that the surgeon know the location and relative importance of the various collateral channels for the large arteries.

The surgeon must also be familiar with the factors which control the development of arterial collaterals and determine whether or not the circulation will be adequate in case of sudden occlusion of an important arterial trunk. Certain of these factors are: the cross section of the collateral bed as compared with the cross section of the main trunk; the diameter of the individual collateral vessels, the elasticity of their walls, and the degree and duration of vasospasm. The blood volume and content and especially the blood pressure are most important and may determine the outcome. As stated by Quiring, the differential in pressure proximal and distal to the site of occlusion is particularly significant, for it is this difference in pressure which largely determines the size of the collateral channels and the

volume of collateral flow. It is obvious, therefore, that the surgeon may have an important part in determining the outcome when important arterial channels are obstructed surgically or otherwise.

In addition to the factors determining whether or not the circulation will prove adequate, one must also consider the effects of ligation, at various sites, on the condition under treatment. In the presence of hemorrhage, not controllable by other measures, ligation of even the largest arteries may be necessary and the vessel must be obstructed at that level which gives the greatest chance for the control of the hemorrhage, even though the collateral circulation may prove inadequate.

Holman recommends ligation of such vessels as the superficial femoral and brachial arteries just distal to a major collateral branch and again just proximal to the next large branch, thus avoiding the expenditure of energy on the expansion of arterial dead space. It has been shown by experimental and clinical work that ligation of the concomitant vein decreases the chance of the development of ischemic gangrene.

When ligation of a large artery is considered advisable, but not imperative, it should be obstructed by some method which will permit prompt reestablishment of its lumen should the anastomotic channels prove inadequate. Halsted's aluminum bands are useful for this purpose for, as shown by Reid and others, they may be removed even after a lapse of four or five days, with an excellent chance of reestablishment of the blood flow. Strips of fascia are also satisfactory for this purpose, but both the metal band and strips of fascia must be applied with care to avoid injury to the intima; otherwise a clot will form.

The exposure of arteries requires a clear knowledge of the anatomy of the site of operation. The incision usually should be made in line with the vessel, centered over the proposed site of ligation. Allowance must be made for disturbance in anatomic relations caused by neoplasms, aneurisms, etc. Careful hemostasis is par*ticularly necessary during the exposure of large arteries, and the manipulations* should be gentle, especially when handling the artery or the tissues immediately adjacent to it. A sharp knife and good sharp dissecting scissors are essential. Nerves appear as solid cords and usually are easily distinguished from arteries, but a nerve resting against an artery transmits pulsation, and this may cause temporary confusion. If the structure is grasped gently between the finger and thumb, it can readily be determined whether the pulsation is transmitted or expansile.

The large arteries have well-developed sheaths, and usually the accompanying vein and nerve are enclosed in the sheath with the artery. In exposing a large artery the sheath should be opened at a distance from important branches. The sheath is picked up with thumb forceps, traction is made to separate it from the artery, *and it is incised in the long axis of the vessel. After a sufficient opening is* made in the vascular sheath, a curved aneurism needle is passed around the artery, starting on the side next to the vein. In this connection it should be recalled that below the axilla and below the knee each artery is accompanied by two veins. The needle is moved to and fro, to separate the vessel and sheath laterally and posteriorly. The ligature is then passed through the eye of the needle and drawn around the vessel. It may occasionally be more convenient to use a small right-angled clamp. One objection to the use of clamps is that the jaws are apt to catch tabs of adjacent tissue. This usually can be prevented by opening and closing the

forceps several times before placing the ligature in its grasp. In a deep wound, however, an aneurism needle is preferable to a clamp.

For large arteries heavy ligatures of silk or other nonabsorbable material should be used. If very large vessels are ligated in continuity, flat ligatures such as tape or strips of fascia are advisable (Fig. 26). All ligature materials have advantages and disadvantages. Fascia lata strips have many advantages but have the serious disadvantage that they usually do not produce permanent occlusion. On the other hand, if permanent occlusion becomes necessary, the vessel may be doubly ligated with heavy silk and divided between the ligatures

The so-called surgeon's knot should never be used in ligating large vessels because it is impossible to tell how much pressure is being taken up by the friction of the tie and how much is being applied to the vessel. The first tie can be fixed by grasping it with a mosquito clamp while the second tie is being made; a third tie should always be placed in order to make the knot more secure. It is not necessary to rupture the intima, but sufficient pressure must be made by the first tie to occlude the vessel. Reid advised compression of large arteries on each side of the site of ligation, so as better to judge the tension necessary to completely occlude the lumen.

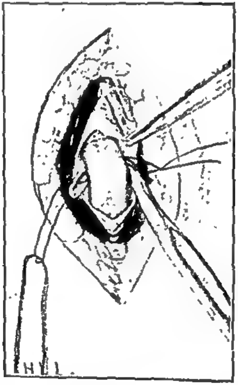

Fig. 26.—Method used to pass heavy ligature material, such as fascia, around an artery.

As a rule, it is safer to divide large arteries, applying two ligatures to the central end, one of them a suture ligature. Also in ligating large arteries, sufficient stump must be left distal to the ligatures to keep them from being rolled off. A good rule is to leave the central segment with a stump as long as the diameter of the vessel

When large vessels are ligated in the presence of gross contamination or active infection, the danger of the ligatures cutting through, with secondary hemorrhage, is greatly increased. Under such circumstances the application of three ligatures,

with division of the artery between the distal ligatures, is very necessary. Heavy nonabsorbable ligatures should be used even though it may be necessary to remove them later. Also as pointed out by Reid, it is safer to leave the divided ends of the vessel projecting into the open wound than to attempt to bury them beneath the adjacent muscle or fascia. The latter procedure simply prevents free drainage and thereby increases the danger.

J. S. Horsley, Jr., found in experimental animals that in order to insure permanent occlusion of a large artery it is necessary to divide it between ligatures. When this is done, the ends retract and a considerable portion of the force of the blood column is utilized in the expansion and protrusion of the free end. Also when

Fig. 27.—Longitudinal section through site of double ligatures on femoral artery, 00 plain catgut, forty days after operation. This shows distinctly the very narrow transverse band of tissue occluding it, the slight break in the fibrous band probably occurred during preparation of the section, magnification about 17 diameters

an artery is divided between ligatures, the endothelial lining of both ends is exposed to the surrounding tissues, granulation tissue grows in, and both stumps of the vessel are soon healed by a solid cicatricial plug that makes for permanent closure and does not permit re-formation of the channel. It was also found that the material used for ligatures was of relatively little importance. Eighty ligations of the brachial, femoral, and carotid arteries of dogs with and without division of the artery were studied at intervals of a few hours to seven months after operation. In four of fifty-two ligations in continuity there was partial reestablishment of the

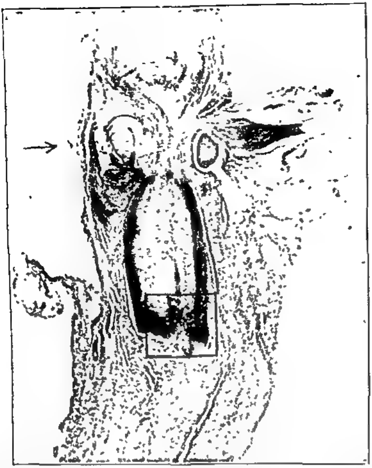

Fig 28.—Longitudinal section of distal ligature of femoral artery after double ligation with 00 plain catgut and division, fifty-eight days after operation; magnification about 17 diameters

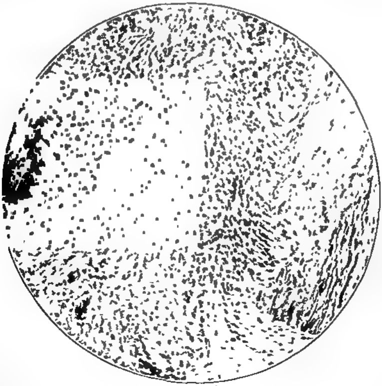

Fig. 29.—Highe ... al arterial end of same slide as Fig. 28: ... low power photo-micrograph; slightly m ... 150 diameters.

arterial channel, whereas in twenty-eight ligations with division of the vessel there was no instance of reestablishment of the channel (Figs. 27, 28, and 29).

Following the occlusion of a large artery the affected part should not be continuously elevated above the level of the heart. Generally it is safer to place the part at about the cardiac level or even slightly below it, but no position should be used continuously. It is advisable alternately to elevate and depress an extremity in which the arterial blood supply is deficient. When such an extremity is allowed to remain in the dependent position, it becomes edematous, and the edema acts to further decrease the blood supply.

TECHNIC OF EXPOSURE AND LIGATION OF CERTAIN LARGE ARTERIES

Innominate Artery

The innominate artery is sometimes ligated for aneurism. It is the largest branch of the arch of the aorta and is about 5 cm. in length. It has its origin opposite the fourth dorsal vertebra; it runs upward, backward, and to the right, and divides, on a level with the upper border of the right sternoclavicular articulation, into the right common carotid and right subclavian arteries. In front of the innominate artery are the manubrium, the right sternoclavicular joint, the remains of the thymus gland, the left innominate vein, the right inferior thyroid vein, and the superior cardiac branches of the right vagus nerve. Posteriorly are the trachea and the right pleura. To the right are the right innominate vein, the right vagus nerve, and the right pleura. To the left are the left common carotid artery, the remains of the thymus gland, the left inferior thyroid vein, and the trachea.

Numerous incisions for exposure of the innominate artery have been described, among them the angular incision of Mott, the horizontal limb of which is made along the upper margin of the clavicle, with section of the sternomastoid muscle. The oblique limb extends up from the medial end of the horizontal limb along the anterior border of the sternomastoid muscle for about 7.5 cm. The incision gives an adequate exposure of the normal innominate artery, but along with all other cervical incisions it is unsuited for operations upon that artery when it is involved by arterial aneurism or by arteriovenous fistula.

In the presence of aneurism or fistula, proximal ligation of the innominate artery by any cervical approach is difficult or even impossible. To cope successfully with innominate aneurism or arteriovenous fistula one must have ready access to the base of the artery, to the entire aneurism or fistulous area, and to the first part of the right carotid and subclavian arteries Under these circumstances a transthoracic or transsternal approach is necessary.

The incision illustrated in Figs. 30, 31, and 32, with certain modifications, has been used by the author for a variety of purposes such as the removal of adherent cysts and tumors of the right anterior superior mediastinum, for the extirpation of densely adherent right upper lobes, and for the exposure of aneurisms of the innominate artery. The incision is started over the right clavicle 4 or 5 cm. from the sternoclavicular joint and is carried across to the mid portion of the suprasternal notch, then is curved downward to the level of the second or third intercostal space and out along that space to the nipple line. In certain pulmonary resections,

it is extended into the axilla The incision is deepened to expose the upper border of the inner end of the clavicle, the sternum, and the intercostal muscles between the second and third or third and fourth cartilages. The skin, fascia and pectoral muscles are elevated and turned to the right, as shown in Fig. 31. The second or, at times, the third costal cartilage and the anterior portion of the corresponding rib are resected subperiosteally. The internal mammary vessels are divided between ligatures and the pleura is entered through the bed of the second rib and cartilage.

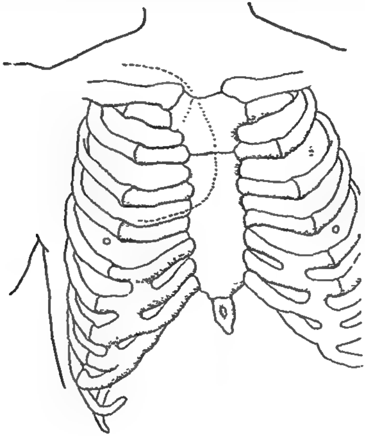

Fig. 30 —Anterior incision for exposure of the upper portion of the mediastinum.

The pleura is incised along with the first intercostal bundle along the sternal border to the junction of the first cartilage with the sternum. The internal mammary vessels are again divided between ligatures and the dissection is extended beneath the sternum and carried upward and to the left to the mid portion of the sternal notch. The communication between the anterior jugular veins is divided between ligatures and the ribbon muscles are separated and retracted to permit the passage of a Gigli saw, which is used to divide the sternum, somewhat as is shown in Fig. 30. It is better to start the section above at the mid portion of the sternal notch, cutting across from there to the first intercostal space. However, the sternum may be sectioned in whatever plane the operator chooses. If it seems necessary to have additional exposure to the left, the operator may take a narrow wedge from the right sternal border at the level of the second cartilage, then section the upper sternum in the midline. The pleura of the anterior wall and that overlying the first part of the subclavian artery are stripped to the right, and the upper portion of the mediastinal pleura is stripped downward and posteriorly, care being taken to avoid injury to the right phrenic nerve. By this approach one can gain an excellent exposure of the superior vena cava, the innominate veins, the innominate

artery, and the division of the innominate to form the right subclavian and right carotid arteries. The remnants of the thymus gland and the fatty areolar tissue between the sternum and the aortic arch and its main branches are dissected away, in part or completely, as seems necessary. In innominate aneurisms it is necessary to ligate and divide the right innominate vein near its juncture with the left innominate to form the superior vena cava. This permits retraction of the left innominate vein and the superior cava forward and somewhat to the left for exposure of the origin of the innominate artery from the arch of the aorta. If occlusion of the innominate is deemed necessary, the right cervicodorsal sympathetic ganglia are easily exposed and resected from this approach. Additional room may be gained by dividing the third costal cartilage at the sternum and retracting it downward.

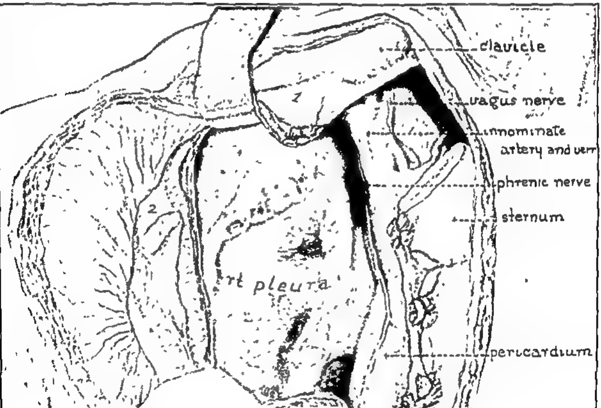

Fig. 31.—The pectoral muscles are mobilized and turned laterally with the skin flap. The second rib is resected, the upper angle of the sternum is divided by a Gigli saw. An incision is then made in the bed of the second rib, and the clavicle and first rib are retracted upward.

In operations upon the innominate artery, Shumacker makes an angular incision over the inner end of the clavicle, then down the mid-sternum. He transsects the sternum at the second or third interspace, then splits the upper segment in the midline. He also resects the inner third of the right clavicle subperiosteally and divides the sternocleidomastoid muscle and the ribbon muscles on that side.

The exposure thus obtained is satisfactory. One of the important advantages of the Shumacker approach to the innominate or subclavian arteries is that it permits preservation of such important collateral channels as the right internal mammary and the upper intercostal arteries. The paired vertebral and thyroid arteries are also important collaterals and should be carefully preserved.

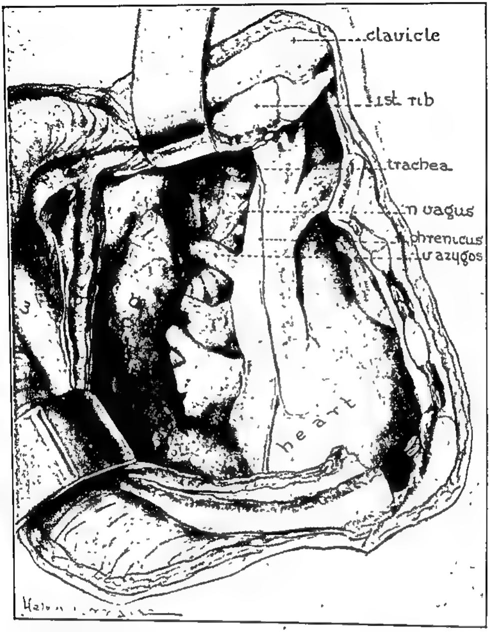

Fig. 32—Exposure of the mediastinal structures, especially the innominate vessels, by this approach (Pleura omitted so that structures may be better shown.)

The Common Carotid Artery

The right common carotid artery arises from the innominate artery and is about 9.5 cm. in length. Its sheath also contains the internal jugular vein, which lies anteriorly and to the lateral side, and the vagus nerve, which lies posterior to and between the artery and vein. The omohyoid muscle crosses the common carotid, and the portion of the artery inferior to this muscle is deeper than that part superior to it.

The left common carotid artery is longer than the right, being about 11 cm in length. It arises from the middle of the arch of the aorta and courses upward and laterally. It is overlapped by the left lung and pleura in its first portion. The omohyoid muscle crosses on the left side as on the right. The left common carotid has anterior to its thoracic portion the manubrium, the remains of the thymus gland, and the left innominate vein. Behind the thoracic portion of the left common carotid are the trachea, esophagus, thoracic duct, and the left recurrent laryngeal nerve. To the left are the pleura and lung, the left vagus nerve, and the left subclavian artery. To the right are the innominate artery, the trachea, the remains of the thymus gland, and the inferior thyroid vein. In the neck both common carotids have similar relations Anteriorly are the skin, superficial fascia, deep cervical fascia, the neck muscles that arise from the sternum, the internal jugular vein, the lingual and facial veins, the superior and middle thyroid veins, the descending branch of the hypoglossal and the ansa hypoglossi nerves. Posteriorly are the vagus nerve, the sympathetic nerves, and the cervical branches of the sympathetic to the heart, the recurrent laryngeal nerve, the inferior thyroid artery; the longus colli and the longus capitis muscles, and the transverse processes of the cervical vertebrae. Laterally are the internal jugular vein and the vagus nerve. Medially are the trachea, esophagus, recurrent laryngeal nerve, branches of the inferior thyroid artery, the thyroid gland, the larynx, and the lower part of the pharynx.

The course of the common carotid artery is illustrated by a line drawn from a point just lateral to the sternoclavicular articulation to a point about midway between the angle of the jaw and the tip of the mastoid process. That portion of this line below the upper border of the thyroid cartilage represents the common carotid. Normally there are no branches from the common carotid. If it is to be ligated below the omohyoid muscle, the incision usually is made in the line of the artery from the lower border of the larynx to the sternoclavicular articulation. After cutting through the skin, superficial fascia, and platysma, the superficial veins that are encountered are doubly ligated and divided. The deep fascia is incised along the anterior border of the sternomastoid, which is retracted laterally. The sternohyoid muscle is retracted toward the midline. The anterior thyroid veins are doubly clamped, divided, and tied The structures which must be protected are the recurrent laryngeal nerve which lies posteromedially, the vagus nerve posterolaterally, and the internal jugular vein anteriorly and laterally.

For ligation of the common carotid above the omohyoid an incision 8 or 9 cm. in length is made along the anterior border of the sternomastoid muscle, centered at the level of the cricoid cartilage The anterior jugular and facial veins should be recognized, and, as they are large, they are doubly clamped, divided, and ligated. The sternomastoid muscle is retracted laterally and the omohyoid muscle is drawn downward and medially. The sheath of the artery is carefully cleared and incised from the medial side to avoid the descending branch of the hypoglossal nerve and the internal jugular vein Ligatures should be passed from the lateral side to protect the internal jugular vein Generally it is desirable to ligate the internal jugular vein when the common carotid artery is occluded

For high ligation of the common carotid artery or for ligation of either the internal or external carotids, a somewhat oblique incision along one of the upper cervical creases gives an entirely adequate exposure and heals more satisfactorily,

with less scarring than the conventional incision along the sternomastoid muscle. The oblique incision starts about 3 cm. below and anterior to the mastoid process and is carried downward and forward along the cervical crease to within about 2 or 2.5 cm. of the midline. It is deepened through the subcutaneous tissue and platysma, and the skin, fascia, and platysma flaps are elevated for 3 or 4 cm. above and below the line of incision. Care is taken to avoid injury to the great auricular nerve and especially to the inframandibular branch of the facial nerve. In freeing and retracting the sternomastoid muscle, it is well to remember that the spinal accessory nerve penetrates that muscle, though usually at a higher level. The rest of the procedure is carried out as previously described.

The collateral circulation for the carotid arteries is largely through the paired arteries such as the thyroids, inferior and superior, the vertebral arteries by extracranial anastomosis and through the circle of Willis, and through the paired branches of the external carotid artery. The collateral to the extracranial tissues of the head and neck is excellent, and in young individuals the collateral circulation to the brain is good, especially when the common carotid is obstructed. The collateral flow is less adequate when the internal carotid is obstructed because of the partial loss of the collateral bed of the paired branches of the external carotid artery. When it is necessary to obstruct the common carotid and both external and internal carotids, as, for example, in the treatment of aneurism at or near the carotid bifurcation, the collateral flow to the brain is considerably diminished.

Since the common carotid artery has no branches between its origin and its division to form the internal and external carotids, Holman's recommendation in regard to avoidance of long useless main trunk segments should be considered and ligation should be done just below the bifurcation when conditions permit. Additional low ligation would be of no value on the left side, and possibly not of sufficient value to justify it on the right side.

Under some circumstances it is desirable to ligate the left common carotid artery within the chest. This is readily accomplished by making a transverse incision over the left second rib and cartilage and resecting the cartilage and a rather long segment of the rib The pleura is entered through the rib bed. With the aid of a rib-spreading retractor a satisfactory exposure is obtained, the pleura is incised just to the right of the left subclavian artery and at the upper border of the aortic arch Special care is exercised to avoid injury to the left vagus and recurrent nerves

The origin of the right common carotid artery is satisfactorily exposed through a transverse incision in one of the lowest cervical creases, the incision to extend from the external jugular vein, forward and medially to the anteromedial border of the sternocleidomastoid muscle. The superficial structures including the platysma are divided and elevated above and below the line of incision. The sternal and clavicular heads of the sternomastoid muscle are separated and the remainder of the operation is carried out as described above.

External Carotid Artery

The external carotid artery is the smaller of the two terminal divisions of the common carotid and is about 6 cm. in length. It extends distally and slightly posteriorly and terminates in the substance of the parotid gland, where it divides to form the internal maxillary and the superficial temporal arteries.

The important structures superficial to this artery are the anterior border of the sternomastoid muscle, the hypoglossal nerve, the lingual and facial veins, the posterior belly of the digastric muscle, the styloglossus muscle, and, higher up, the branches of the facial nerve and the parotid gland. Posterolaterally are the internal carotid artery, the vagus nerve, and the superior laryngeal nerve. Medially are the hyoid bone and the pharynx, and the deeper part of the parotid gland.

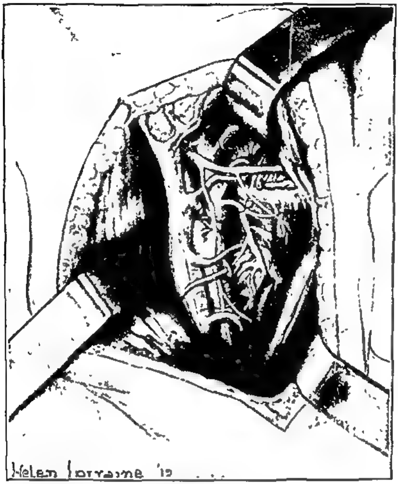

Fig. 33.—Ligation of the external carotid artery and the first four of its branches. A ligature has also been placed around the common carotid artery. The hypoglossal nerve is shown.

The external carotid may be ligated either above or below the digastric muscle, the place of election being below that muscle. The conventional incision, about 7.5 cm. long, is made just posterior to the anterior border of the sternomastoid muscle and from the level of the middle of the thyroid cartilage to near the level of the angle of the jaw. If the sternomastoid muscle is large, approach to the artery may be made easier by splitting the fibers of this muscle, but ordinarily it is retracted outward. The posterior belly of the digastric muscle is seen at the upper angle of the wound, and then one finds the hypoglossal nerve, crossing the external carotid artery. The thyroid, lingual, and facial veins may be avoided but if too much in the way they may be clamped, divided, and tied. The ligature should be placed below the superior thyroid artery. Generally when tying the external carotid preliminary to operations about the oral cavity or face, it is best also to tie the superior thyroid, the lingual and the other accessible branches of the external carotid, as the

collateral circulation is very abundant. Through the same incision, continued slightly upward, the external carotid may be tied above the digastric muscle, though ligation at this level rarely is indicated (Fig. 33).

Internal Carotid Artery

The internal carotid is ligated through an incision similar to that used in ligating the external carotid. The bifurcation of the common carotid is exposed, and the external carotid is identified by its anterior location and by its branches; the internal carotid gives off no branches in the neck. The internal carotid at its origin is slightly posterolateral to the external carotid but it soon occupies a deeper position in the neck. It is tied near its origin. The ligature is passed from the side of the internal jugular vein, care being taken to avoid injury to this vein and also to the vagus nerve, as well as the ascending pharyngeal branch of the external carotid artery.

Both the external and internal carotid arteries are readily exposed by oblique incisions along a cervical crease at about the level of the hyoid bone. The incision is carried through the platysma, which is separated from the underlying structures above and below the line of incision. The inframandibular branch of the facial nerve and the auricular nerve should be protected.

Subclavian Artery

The subclavian artery is preferably ligated in its third portion, but it is sometimes necessary to ligate its first part Ligation of the first part of the subclavian is somewhat more difficult than ligation of either the second or the third parts, especially on the left side.

The right subclavian artery arises from the innominate artery and is about 7.5 cm. in length, the left subclavian is considerably longer since it arises from the arch of the aorta The subclavian arteries are divided into three portions, the first portion extending from their origins to the medial borders of the scalenus anticus muscle The important structures in front of the first portion of the right subclavian are the sternomastoid, the sternohyoid, and sternothyroid muscles, the right innominate vein, the internal jugular vein, the vagus and phrenic nerves, and the cardiac branches of the sympathetic and of the vagus nerves. Behind are the sympathetic nerves, the recurrent laryngeal nerve, the longus colli muscle, the transverse processes of the seventh cervical and the first thoracic vertebrae, the apex of the right lung, the pleura, and the neck of the first rib. Below are the pleura and lung, the recurrent laryngeal nerve, and the subclavian vein. Although the first portion of the left subclavian is longer than on the right, the relations are much the same except that the thoracic duct, the subclavian vein, and the common carotid artery are in front, and the esophagus, the thoracic duct, and the carotid are medial. The second portion of the subclavian artery is from 1.75 to 2.5 cm long and lies behind the scalenus anticus muscle, which separates the subclavian artery from the subclavian vein. Both the first and second portions of the artery are overlapped by the sternomastoid muscle. The phrenic nerve crosses obliquely the lower anterior surface of the scalenus anticus muscle. The trunks of the brachial plexus are located above and lateral to this part of the vessel. The third portion of the subclavian artery lies in the subclavian triangle, whose borders are

the sternomastoid muscle, the posterior belly of the omohyoid muscle, and the upper border of the clavicle. The important structures in front of the third portion of the subclavian are the transverse scapular artery and the external jugular and subclavian veins. Behind are the scalenus medius muscle and the lowest trunk of the brachial plexus. Above and laterally are the upper trunks of the brachial plexus, and below is the first rib. As indicated when circumstances permit, the third part of the subclavian is the site for ligation.

Ligation of the first portion of the right subclavian artery can be done by the same angular incision formerly used for exposing the innominate, but, if the artery is essentially normal, this type of incision is unnecessary, and when the vessel is involved by aneurism or arteriovenous fistula, the approach is inadequate and unsatisfactory. In either of these conditions it is essential that the clavicle be resected; otherwise it is almost if not quite impossible to gain complete control of bleeding. The inner end of the clavicle is resected subperiosteally by Elkin, Shumacker, and Holman and is best disarticulated from the sternum. The clavicle is exposed through a straight incision along its superior border. Elkin and Holman do not replace the bone and simply suture the periosteum. Shumacker recommends chipping the resected clavicular segment and filling the periosteum of the clavicle with these chips; he feels that this hastens regeneration. On the left side, the first portion of the subclavian is well exposed transpleurally through the incision recommended for exposure of the left common carotid artery.

The second portion of either subclavian artery, that portion distal to the first group of important branches, may be ligated through a transverse incision starting just above the medial end of the clavicle and extending laterally for 5 to [illegible] cm. The clavicular portion of the sternocleidomastoid muscle is divided and the carotid artery and internal jugular vein are retracted toward the midline. The anterior scalenus muscle is exposed and the phrenic nerve and subclavian vein are separated from the anterior surface of this muscle. The anterior scalenus is then carefully separated from the trunks of the brachial plexus laterally and the subclavian artery posteriorly. The muscle is divided near its attachment to the first rib, and the second portion of the artery is thus exposed. In case of aneurism or arteriovenous fistula, preliminary resection of the medial one-third to one-half of the clavicle is necessary.

The third portion of the subclavian artery can be ligated by making an incision just above the clavicle. The skin is drawn down and the incision is made over the clavicle, beginning at the posterior border of the sternocleidomastoid muscle and extending laterally and posteriorly for a distance of about [illegible] or 9 cm. When the skin is relaxed, the incision should be about 1 cm. above the clavicle. The margins of the sternocleidomastoid and trapezius muscles are exposed and incised if necessary. The external jugular vein is doubly ligated and divided, as are the veins which empty into it. The transverse cervical and the suprascapular arteries usually run near the field but they should be preserved if at all possible as they are important collateral channels. The lateral margin of the scalenus anticus muscle, which lies just under the sternomastoid muscle, is identified and followed down to the artery. The lowest trunk of the brachial plexus and the subclavian vein, which lies in front of and below the artery, are exposed. The pleura must be protected. The sheath is opened and the ligature is passed from the brachial plexus side, avoiding the pleura and the subclavian vein (Fig. 34). When ligating the sub-

clavian artery it may be wise to resect the stellate and upper thoracic sympathetic ganglia to make more certain of an adequate collateral blood supply to the upper extremity. The stellate ganglion lies just posterior to and below the origin of the vertebral artery and is readily exposed after section of the anterior scalenus muscle.

It was formerly felt that the collateral circulation for the first part of the subclavian artery was not especially good, but it has been shown in recent years that the intrathoracic part of the left subclavian and that portion of the right subclavian central to the vertebral and internal mammary arteries can be occluded in children and young adults with little risk of serious ischemia of the corresponding upper extremity. Even in older patients the risk usually is not great. There are many collateral channels, but the more important ones are by way of the paired arteries, such as the vertebral, the internal mammary, and the thyroid arteries, both inferior and superior.

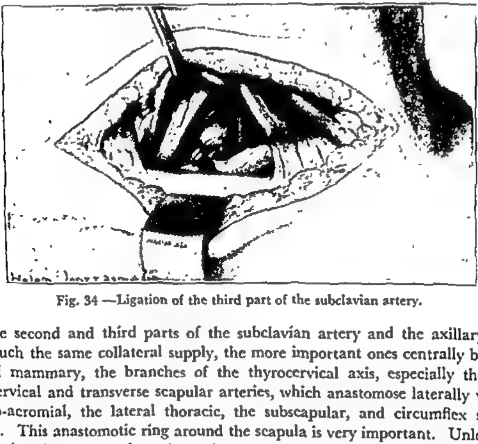

Fig. 34 —Ligation of the third part of the subclavian artery.

The second and third parts of the subclavian artery and the axillary artery have much the same collateral supply, the more important ones centrally being the internal mammary, the branches of the thyrocervical axis, especially the transverse cervical and transverse scapular arteries, which anastomose laterally with the thoraco-acromial, the lateral thoracic, the subscapular, and circumflex scapular arteries. This anastomotic ring around the scapula is very important. Unless there is extensive damage to the collateral vessels, there is no great danger of serious ischemia from obstruction of either of these arteries. However, as stated elsewhere, when an artery of the size of the common or internal carotids, the subclavians, or the axillaries is tied, it is necessary that every precaution be taken to assure an adequate blood supply to the involved area. Careful preservation of all important collateral channels is necessary, and sympathectomy usually is advisable.

Vertebral Artery

The vertebral artery is the largest and usually the first branch of the subclavian and may be exposed by the incision used in ligating the common carotid in its proximal portion or that used for the second portion of the subclavian. By the former route, after exposing the sheath of the common carotid, this vessel, the

patient the ligature was applied just below the diaphragm. Death occurred from hemorrhage, the result of the ligature cutting through.

In a personal case reported by Vaughan, Brasdor's method of distal ligation was adopted; the ligature, a piece of tape, was placed around the aorta below the aneurism just distal to the origin of the inferior mesenteric artery. The aneurism had developed from the left side of the aorta behind the pancreas and about opposite the origin of the superior mesenteric artery. The patient made a satisfactory clinical recovery and died two years and one month after operation. Necropsy showed the aneurism to be considerably larger than at the time of the operation but it had not ruptured. It contained a large firm reddish-white clot and relatively little fluid blood. Death was apparently not due to the aneurism, though the aneurism had not been cured.

In 1925 Rudolph Matas reported, before the American Surgical Association, a case of ligation of the aorta for abdominal aneurism, with the patient surviving the operation for more than a year and dying from a disease unrelated to the aneurism.

In 1926 Brooks reported a case in which he ligated the abdominal aorta for aneurism. The patient was carefully studied before operation and it seemed that a satisfactory collateral circulation had been established. There was no pulsation of the left femoral artery and very feeble pulsation of the right femoral artery. The aneurism was exposed and found to fill the lower abdomen and to extend far out in the left flank. The abdominal aorta proximal to the aneurism appeared normal. An attempt was made to extirpate the aneurismal sac but this was abandoned because an injury to its wall was followed by a terrific hemorrhage. This was controlled by inserting the thumb through the rent in the sac. The aorta was ligated with a strip of fascia lata about 0.5 cm in width, which was passed twice around the vessel just distal to the origin of the inferior mesenteric artery. This was drawn tightly enough to stop all distal pulsation, and a braided silk ligature was tied around the aorta between this and the aneurism, there being a space of about 1 cm between the two ligatures. The patient developed pneumonia but made a satisfactory recovery. The aneurism became smaller and at no time pulsated, but pulsation reappeared in the left femoral artery. The patient was relieved of pain and returned to work, but about three months later he developed intestinal obstruction from which he died in a few hours. Necropsy showed that the aneurism had shrunken to a firm mass "about the size of a small orange which was firmly fixed to the vertebral column at the site of the promontory of the sacrum." The aneurismal sac was completely obliterated

Ligation of the abdominal aorta below the renal arteries is best done through a left paramedian incision which should be 20 to 25 cm. in length and centered at the umbilicus. The medial border of the rectus muscle is separated from the sheath and retracted laterally. Special care should be taken to avoid injury to the superior and deep epigastric arteries, as these are important collateral channels. The posterior sheath of the rectus muscle and the peritoneum are incised, the patient is placed in the Trendelenburg position, and the intestines are packed upward. The posterior parietal peritoneum is carefully incised over the left anterior surface of the aorta, care being taken to avoid injury to the branches of the inferior mesenteric artery if the ligation is to be below the origin of this vessel. If the

ligation is to be above the origin of the inferior mesenteric artery, great care must be exercised to avoid injury to the vessels in the root of the mesentery. Careful blunt dissection is necessary to accomplish this.

When ligation is done above the inferior mesenteric artery, the third portion of the duodenum is exposed, gently separated from the surrounding tissues, and retracted upward. This brings the aorta into view, but only a limited exposure is possible at this level. If sufficient room can be obtained, it would seem desirable to occlude the aorta, as far proximally as possible, by a heavy strip of fascia lata, which should be passed around the vessel twice before it is fixed by mattress sutures of silk. If the vessel is to be permanently occluded, two ligatures of heavy braided silk are placed below the fascial band, and, if the silk ligatures can be placed sufficiently far apart, the vessel wall should be divided between them. If the condition of the arterial wall permits, division and suture may be preferable to the use of ligatures. Fascia is used to occlude the vessel proximally as it does not tend to cut through the wall of large arteries as do other ligature materials. This same type of procedure should be carried out when the vessel is occluded below the inferior mesenteric artery, and fortunately more room is available at this level unless the aneurism itself interferes with the exposure, as may occur.

As previously stated, it is doubtful whether ligation of the abdominal aorta should be attempted above the level of the superior mesenteric and renal arteries. If occlusion above this level is indicated, it would seem wiser to follow the suggestion made by Halsted and Reid to occlude the lower portion of the thoracic aorta, as it is much less difficult to expose and occlusion at this level gives a better chance for the development of an adequate collateral circulation to the abdominal organs, especially to the kidneys. Unless immediate occlusion is imperative, as in ruptured abdominal aneurism, it seems wiser first to partially occlude the lower thoracic aorta, either by fascia or by a metal band, of the type recommended by Halsted, Matas, and Reid. Partial occlusion by a strip of fascia is preferable as the first step of the operation. Heavy pieces of braided silk should be left looped around the vessel at proper levels distal to the fascial band for use in drawing ligatures around the vessel at a later stage At the second stage the aorta should be completely occluded by fascia proximally, then divided distally and the ends sutured. If the wall is too sclerotic to hold sutures, it should be divided between heavy braided silk ligatures. Intervening intercostal vessels must be ligated, but all other collaterals should be protected.

We have occluded the abdominal aorta above the inferior mesenteric artery a number of times and in no instance has there been evidence of serious interference with the blood supply to the colon, but it should be noted that these patients had aortic aneurisms which no doubt had resulted in an increased collateral bed. However, these results are in keeping with the experimental work done by Archibald more than forty years ago Archibald showed that in dogs the main stem of the inferior mesenteric artery could be tied with very slight risk of producing ischemic necrosis of the colon. On the other hand, when the aorta is tied at that level there is always serious ischemia of the lower extremities and a considerable percentage will develop ischemic gangrene.

The collateral circulation for the abdominal aorta is, as has been indicated, usually inadequate below the renal arteries and always inadequate above the renal arteries. However, there are numerous collateral channels, the most important ones

The genital branch of the genitofemoral nerve lies in front of the artery in its lower third. The distal portion of the external iliac artery is crossed by the spermatic artery and vein and the vas deferens in the male, and by the ovarian artery and vein in the female. Also at this point the deep epigastric artery, a very important collateral branch, arises from the anterior surface of the external iliac and courses forward and medially. Posteriorly are the external iliac vein and the medial border of the psoas major muscle. Laterally is the psoas major muscle.

The external iliac artery can be well exposed by the incision used for the common and internal iliacs, but if ligation is to be done near the inguinal ligament, it can be done more satisfactorily by a muscle-splitting incision or by an extraperitoneal approach through an incision parallel to the inguinal ligament and about 1 cm. above that ligament. When the peritoneum is stripped up, care should be taken to protect the branches of the external iliac artery, especially the deep epigastric, because of its value as a collateral channel. Even though the peritoneum is not opened, the Trendelenburg position is a great help. The sheath of the artery is opened from the lateral side to avoid injury to the vein and care is taken to protect the genital branch of the genitofemoral nerve. The artery is ligated 3 or 4 cm. above the inguinal ligament.

The collateral circulation for the common and external iliac arteries is relatively satisfactory, far better than for the terminal aorta.

When one common iliac artery is occluded, the paired branches of the internal iliac arteries, such as the uterines in the female, the pudendals in the male, and the vesicals, take part in the collateral supply to the tissues distal to the obstruction, thereby greatly increasing the likelihood of the development of an adequate blood flow.

The collateral circulation for the external iliac arteries is better than that for the common femoral arteries, for the deep circumflex iliac and the deep epigastric, both important collateral channels, form a part of the collateral bed for the external iliacs.

The collateral bed for the internal iliac (hypogastric) arteries is excellent, so good in the female that only slight risk is incurred when both internal iliacs are ligated. The chief collaterals for the internal iliacs are the superior hemorrhoidal arteries, connecting with the middle and inferior hemorrhoidals, the anastomoses between the gluteal and obturator branches of the internal iliac and the lateral and medial femoral circumflex arteries. The uterine arteries, in the female, and the pudendal arteries in the male act as important collateral channels

LIGATION OF THE FEMORAL ARTERY

The femoral artery, a continuation of the external iliac, begins immediately behind the inguinal ligament about midway between the anterior-superior spine of the ilium and the symphysis pubis. It passes down the anterior and medial side of the thigh to the junction of the middle and lower thirds of the thigh, where it continues as the popliteal artery. The superficial part lies in the femoral (Scarpa's) triangle, which is bounded laterally by the medial margin of the sartorius muscle and medially by the margin of the adductor longus Its base is formed by the inguinal ligament. The apex of the femoral triangle is the point at which the medial

margin of the sartorius crosses the adductor longus. The lower third of the femoral artery passes through the adductor (Hunter's) canal, which is an aponeurotic channel extending from the apex of the femoral triangle to the lower part of the adductor magnus muscle.

The common femoral artery, extending from the inguinal ligament to the origin of the profunda femoris, is about 3.75 cm. long. The important structures in front are the lumboinguinal nerve and the superficial circumflex iliac vein. Behind are the psoas and pectineus muscles; laterally is the femoral nerve, and medially the femoral vein. The relations of the femoral artery from the origin of the profunda femoris to the apex of the femoral triangle are, in front, the lumboinguinal nerve and, behind, the femoral vein, the profunda vein, and the profunda artery, in the order named; then the pectineus muscle and the adductor longus muscle. Laterally are the branches of the femoral nerve, the saphenous and the nerve to the vastus medialis. Medially is the femoral vein, which assumes a position posterior to the artery at the apex of the femoral triangle. The third division of the femoral artery is that in the adductor canal, where it is quite deep. Behind are the femoral vein, which becomes slightly lateral in its lower portion, and the vastus medialis and adductor muscles. Laterally is the vastus medialis and medially are the adductor longus above and the adductor magnus below.

The optimum point, for ligation of the superficial femoral artery, is immediately distal to the origin of the profunda femoris artery. The apex of the femoral triangle is about 8.75 cm. below the inguinal ligament and the profunda artery arises about 3.75 cm. below the inguinal ligament The site for ligation therefore lies a little above the halfway mark between the inguinal ligament and the apex of the femoral triangle. The artery overlies the vein to a considerable degree so care must be exercised in separating the two so that the vein will not be torn. The saphenous nerve lies anterolateral to the artery.

Ligation of the common femoral artery carries a serious risk of ischemic gangrene, so, when ligation of the common femoral is indicated, it is safer to ligate the external iliac if associated circumstances permit it, thus gaining the benefit of the deep epigastric artery as a collateral channel.

The common femoral artery can be exposed by an incision about 7.5 cm. long beginning just above the inguinal ligament and extending down in the line of the artery. The superficial circumflex iliac, superficial epigastric, and superficial external pudendal vessels should be avoided, also the lumboinguinal nerve, which is in front of and a little lateral to the artery. The femoral nerve lies farther to the lateral side of the artery and outside its sheath The ligature is passed from the medial side, avoiding injury to the femoral vein (Fig. 36). The common femoral artery may also be readily exposed by an incision parallel to the inguinal ligament and about 1 5 cm. below it

The incision for ligation of the superficial femoral artery is started about 2 cm. below the inguinal ligament directly over the common femoral artery and is directed distally and slightly to the medial side of the thigh along the course of the artery, for about 7.5 cm. The common femoral artery lies superficially, covered only by skin, subcutaneous tissue, and fascia and is exposed by careful sharp dissection. The medial edge of the sartorius is freed and the dissection is extended below the division of the common femoral to expose the proximal 2.5 to 3 cm. of the superficial

femoral artery. The artery is separated from the vein by carefully splitting the common sheath with a sharp knife or small dissecting scissors. At this level, the artery often almost completely overlies the vein. When the artery and vein have been completely separated, three medium, braided silk ligatures are applied, the proximal one within a centimeter of the profunda artery, the distal one approximately 2.5 cm. away, so that the two distal ligatures may be roughly 1 5 cm. apart. Section of the artery midway between the distal ligatures leaves a stump beyond the ligature of about 0.75 cm.; a safe margin. In arteries the size of the iliacs or femorals it is a good plan to follow Reid's suggestion, that an assistant compress the artery above and below while the ligatures are being tied.

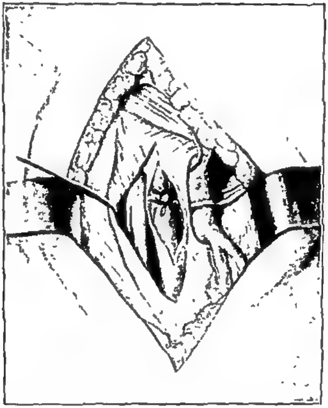

Fig 36.—Ligation of the right femoral artery just below Poupart's ligament. Three ligatures should be placed and the artery severed between the distal two ligatures.

When it becomes necessary to ligate certain arteries, such as the common iliac, common femoral, or the popliteal, it is usually advisable to ligate the concomitant vein. More important is preliminary interruption of the lumbar sympathetic chain on that side If the artery is ligated as an emergency, it is wise to block the lumbar sympathetics by injecting procaine solution immediately upon completion of the operation Should the distal circulation improve following the block but soon show evidence of deterioration, one will do well to proceed promptly with surgical interruption of the lumbar sympathetics In case of the aorta or common iliac arteries, the sympathectomy may be done through the incision used to expose the artery.

The collateral circulation for the common femoral artery is not especially rich. Two important proximal collateral channels are the deep circumflex iliac and the obturator arteries which form anastomoses with the lateral and medial circumflex femoral arteries Sudden occlusion of the common femoral artery frequently is followed by severe ischemia and not infrequently by ischemic gangrene.

The collateral bed for the superficial femoral artery is good, the main collaterals being the descending iliofemoral circumflex artery and the profunda femoris, by far the most important. As pointed out elsewhere, Holman's principle of ligation just below and just above important collaterals is especially applicable in relation o the superficial femoral artery. Proximal ligation immediately distal to the origin f the profunda femoris and distal ligation above the highest geniculate artery sacfice only a few small collaterals and a large arterial dead space is avoided.

IGATION OF THE POPLITEAL ARTERY

The popliteal artery is a continuation of the femoral and extends from the opening in the adductor magnus at the junction of the middle and lower thirds of the thigh downward and laterally through the popliteal space to a point behind the knee joint and then directly downward to the lower border of the popliteus muscle, where it divides to form the anterior and posterior tibial arteries. The important structures in front of the popliteal artery are the posterior surface of the femur, the oblique popliteal ligament, the posterior surface of the upper end of the tibia, and the popliteus muscle. Posteriorly, or superficially, are the medial head of the gastrocnemius muscle, the aponeurotic arch of the soleus muscle, and the popliteal vein, which lies posterior to the artery throughout its course but crosses obliquely from the lateral to the medial side. The vein is in close contact with the artery. The tibial nerve is posterior to the popliteal vein, and is first lateral and posterior, then crosses the popliteal vein and artery and assumes a posterior and medial position in the distal part of the popliteal space.

The artery may be tied either in its proximal or distal portion. It may be approached in its proximal portion from the medial aspect of the thigh or posteriorly from the medial part of the popliteal space In its distal portion it is exposed through a transverse or an S-shaped incision. A straight incision carried perpendicularly across the crease of the knee leads to contracture and should not be used. For the medial approach to the proximal portion of the artery an incision about 8 or 9 cm. long is made, beginning at the junction of the middle and lower thirds of the thigh and running distally parallel with and immediately posterior to the tendon of the adductor magnus muscle The anterior edge of the sartorius is retracted posteriorly, together with the long saphenous vein, while the tendon of the adductor magnus is identified and drawn forward. The artery is found between this tendon and the semimembranosus muscle. The popliteal vein lies superficial to the artery and the tibial nerve is superficial to the vein. Ligation of the popliteal artery is done, preferably in its proximal portion If ligation is necessary in the distal portion of the popliteal space, a transverse incision, made at the level of the flexion crease, is preferable. The skin and fascia are elevated to expose the heads of the gastrocnemius muscle, which are retracted to each side. The nerve and vein are retracted medially and the ligature is passed around the artery from that side. If possible, the popliteal artery should be occluded above the inferior geniculate arteries. Ligation of the popliteal vein is advisable when the popliteal artery is occluded

The collateral supply for the popliteal artery is not always adequate, as so often is the case where there is only a small muscle mass surrounding an artery. The descending branch of the lateral femoral circumflex artery, the highest geniculate,

and the lateral and medial superior geniculates are important proximal coll vessels, while the lateral and medial inferior geniculates and the anterior tibi current are the chief distal collaterals. The greatest care should therefore be cised to protect these collateral vessels during exposure of the popliteal artery.

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CHAPTER 8

BLOOD VESSEL SUTURE; ARTERIAL EMBOLECTOMY

I. A. Bigger

BLOOD VESSEL SUTURE

At the time of the publication of the fifth edition of this book, only a little more than a decade ago, blood vessel suture was an infrequent undertaking in most hospitals. The situation now is altogether different, for in a number of hospitals blood vessel suture is of daily occurrence and in the majority of hospitals it is performed often enough to be considered a more or less routine procedure. A number of factors were responsible for this development. The large number of vascular injuries encountered in modern warfare has played a considerable part, but the operations developed by Gross, Blalock, Crafoord, and Potts for cure or relief of anomalies of the heart and the great vessels at the base of the heart probably have been an even more important stimulus. At any rate, the suturing of blood vessels is now so frequently done that every surgeon should be familiar with the technic. Actually there is nothing unusual or mysterious about the technic of blood vessel suture; the instruments and sutures are somewhat more delicate and gentleness is perhaps even more essential in vascular surgery than elsewhere. However, the principles involved are the same—minimal trauma to tissue, complete hemostasis, careful asepsis. Since operation upon blood vessels and operations performed under local anesthesia exact gentleness of the surgeon, it might be well to require trainees in surgery to demonstrate a certain degree of proficiency in both these fields before qualifying them as safe and sound surgeons. In the one instance, adverse reaction to roughness is shown by the tissues, in the other by the patient. The only special instruments required for arterial suture are small tissue forceps, small hemostats (so-called mosquito clamps), small and efficient needle holders, and especially constructed clamps for control of bleeding. There are now a considerable number and variety of such clamps available, the majority of them designed and constructed for a specific purpose. The more important ones are the Potts-Smith clamp for lateral anastomosis of the aorta and pulmonary artery, the Blalock clamp for end-to-side anastomoses, and the Potts toothed clamps for division of the patent ductus and for anastomosis of the aorta in the cure of coarctation. This latter clamp is a most ingenious instrument and may be used to advantage in a number of situations other than those for which it was devised. One also needs a few simple spring clamps or bulldog clamps for temporary obstruction of blood vessels. The sutures should be fine and of nonabsorbable material, preferably silk. Under most circumstances sutures of four 0 to six 0 silk swaged on fine needles are satisfactory. Both straight and

curved needles should be available. Many surgeons prefer having the sutures treated with sterile mineral oil or petrolatum before they are used. This probably is of no great importance except that it decreases the drag or resistance of the suture and thus makes it somewhat easier to snug up when a continuous suture is being inserted, as, for example, in the Blalock operation of end-to-side anastomosis of a systemic artery with a pulmonary artery.

There are a number of technics for suturing blood vessels, all more or less satisfactory. On theoretical grounds, interrupted, everting, mattress sutures should be better for end-to-end suture, especially in operations upon children, for it would seem they would be less likely to interfere with enlargement or growth of the anastomotic ring. In practice this appears to be of little importance. Generally speaking, *continuous sutures are more satisfactory for they require less time, give more accurate coaptation and, therefore, more complete hemostasis.* Carrel used the continuous over-and-over suture (Figs. 37 and 38) with remarkable success, and a good

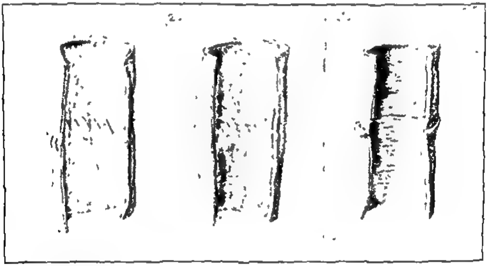


Fig. 37 Fig. 38 Fig. 39

Fig. 37.—This drawing, reproduced from Guthrie, shows the lumen of a blood vessel immediately after it has been sutured by the method of Carrel. Note the large amount of thread exposed in the lumen.

Fig. 38.—This drawing, also from Guthrie, shows the lumen of a blood vessel several weeks after successful suture. The stitches have been covered by endothelium, which is still transparent.

Fig. 39.—This drawing shows the eversion produced by the double mattress stitch and the consequent absence of any raw surfaces in the lumen of the vessel.

many surgeons prefer that technic. Crafoord uses a continuous over-and-over suture, which does not penetrate the intima, and feels that, when accurately placed, it gives anatomic approximation of the various layers of the vessel wall. Gross, Blalock, and many others prefer a continuous, everting mattress suture because it approximates intima to intima, exposes less suture material to the blood stream, and does not narrow the lumen at the anastomotic site (Fig. 39). J. Shelton Horsley preferred the latter technic for the same reasons. All told, it does seem to have certain advantages over the other methods of suture and it is reasonably certain that one not especially expert in vascular surgery will obtain more satisfactory results by this technic. *In arterial anastomosis the superficial portion of the adventitia must* be removed from the ends of the artery, and, when large arteries are involved, the

loose part of the adventitia should be removed from the area to be occupied by the obstructing clamps; otherwise, the vessel tends to slip from their grasp.

In addition to the procedures mentioned, vascular suture is indicated in wounds of arteries, especially those made by cutting instruments. More extensive wounds of important arteries, such as the carotids, iliacs, common femorals, etc., not amenable to direct suture may be treated by excision of the devitalized segment and end-to-end suture, or when this is not possible by the use of vein grafts. Arterial embolectomy is another rather frequent indication for suture. Arterial suture is often of value in the cure of traumatic arterial aneurisms and arteriovenous fistulas.

End-to-end arteriovenous anastomosis with reversal of the circulation was formerly thought to be of value in the prevention of ischemic gangrene in certain obstructive lesions of the main arteries, especially those of the lower extremities. It now appears that any improvement which may have been noted following this procedure was due to occurrences incidental to the operation and not to the passage of arterial blood through the veins. The resultant obstruction of the concomitant veins may well have brought some improvement in certain instances. With the failure to improve the blood supply to the extremities by arteriovenous anastomosis in mind, the recent work by Beck and his associates directed toward increasing the blood supply to the central nervous system and to the myocardium by such means is especially interesting. It appears, however, that the anatomic peculiarities of the cardiac venous system may increase the chance of success.

Blakemore and his associates have developed an ingenious nonsuture method of blood vessel anastomosis which serves an excellent purpose. The method is simple, easy of accomplishment, and can be performed in a short time.

The technic is briefly as follows: the ends of the artery to be anastomosed are dissected free for a short distance and the adventitia is dissected away in much the same manner as for suture. A suitable vein (possibly the concomitant vein) is freed up and a section of sufficient length is resected The ends of the venous segment are then passed through Vitallium cannulae and turned back to form a collar over the ends of the cannulae, thus giving an endothelium-lined tube and endothelial covering of each end. The endothelium-covered ends of the cannulae are then inserted into the ends of the artery and the artery is fixed to the cannula by silk ligatures, which are prevented from slipping by ridges or shoulders on the cannulae. When the anastomosis is complete, the entire vascular channel is lined by endothelium with no foreign material presenting in the lumen. The objection to the method is, of course, the use of so large an amount of foreign material. However, it is possible to bridge arterial defects by this method under circumstances in which suture would be difficult or impossible

ARTERIAL EMBOLECTOMY

Peripheral arterial embolization is, as a rule, the result of clot formation in the left side of the heart. Mural thrombi may form over an infarcted area, but in a large proportion of cases peripheral emboli develop in patients with auricular fibrillation, usually, though not necessarily, of long standing. Furthermore the auricular appendage is the site of such clot formation. With these facts in mind, Madden, Longmire, and a number of other surgeons have resected the left auricular appendage in patients with auricular fibrillation who had thrown one or more ar-

terial emboli. Also in at least one instance the right auricular appendage has been resected in a patient throwing pulmonary emboli. The results have been encouraging, but the number of such operations so far reported is too small to justify conclusions relative to the value of the procedure.

Emboli thrown into the circulation lodge at main arterial bifurcations or at the site of origin of large branches, such as the profunda brachii, the bifurcation of the aorta, or the origin of the deep femoral artery. They are diagnosed more frequently and probably actually lodge more frequently in the arteries supplying the lower extremities. It is said that approximately 50 per cent of all peripheral emboli lodge at the origin of the deep femoral artery. However, it should be remembered that they may lodge in any part of the body. Embolism to the superior mesenteric artery is not rare, and while I know of no attempt to remove an embolus from that artery, I can see no reason why such an undertaking might not be successful. The difficulty, of course, lies in making the diagnosis early enough.

Embolectomy is the treatment of choice when important arteries of either the upper or lower extremities are blocked. However, satisfactory results are obtained only when the operation is performed early, the earlier the better. Embolectomy within the first six to eight hours gives an excellent chance for complete restoration of the circulation. Under twelve to fifteen hours there are fair chances of success, but when twenty-four or more hours have passed, the outlook is poor. There are a number of reasons why the results become less satisfactory as the time interval increases between lodgment of the embolus and its removal. The intima is progressively damaged by prolonged contact with the embolus, and secondary thrombosis becomes increasingly likely. The extent of collateral obstruction increases because of the formation of clot adjacent to the embolus, and finally the tissues distal to the obstruction including the lining of the vessels suffer increasingly from anoxia, so that extensive thrombus formation occurs distal to the embolus. At this stage, treatment obviously will be of no avail.

There are also a number of reasons for the high incidence of gangrene following the embolic obstruction of major arteries. First and possibly most important is the fact that when an embolus lodges at the origin of a large branch or division of an artery such as the deep femoral, it usually occludes the large division as well as the main trunk, thereby blocking a large proportion of the collaterals. Also the sudden blockage seems to cause spasm of the collateral vessels. This spasm may be relieved by interrupting the sympathetic nerves supplying that area.

Sympathetic interruption may be accomplished by surgery or by procaine block; the latter method should be tried first. If the result is but transient, surgical resection of the sympathetic ganglia is advisable, especially when embolectomy is not feasible or has proved unsatisfactory. Even when embolectomy seems satisfactory, sympathetic procaine blocks should be continued until vasospasm is relieved

When a patient with embolic obstruction of a major artery is seen within the early hours after lodgment of the embolus, embolectomy should be undertaken without delay unless there are very important contraindications to surgery. Also, the larger the artery obstructed, the greater the necessity for immediate action. For example, in true saddle embolus at the bifurcation of the aorta, with obstruction of both iliac arteries, the prognosis is extremely poor unless the embolus is removed promptly. There are now a considerable number of successful aortic embolectomies

in the literature, and with the current improvements in anesthesia, etc., a high percentage of such patients should be saved by early operation.

Approach to the aorta may be extraperitoneal or transperitoneal. The decision as to the route should be made on the basis of the existing circumstances, special consideration being given the patient's general condition and ability to withstand surgery. If the patient's condition seems satisfactory, the transperitoneal approach is better. The aorta and both iliac arteries are more readily exposed, and after the embolus has been removed, one can with almost no additional trauma examine the bifurcation of both common iliacs for other emboli. This is of some importance, for multiple emboli not infrequently occur, and there is also a chance that a fragment will break away from the main mass and obstruct some distal vessel.

A left paramedian incision centering at the umbilicus is suitable for the transperitoneal approach. For the extraperitoneal approach one may use a left transverse incision at the level of the umbilicus, starting 2 to 3 cm. medial to the lateral border of the rectus muscle and extending laterally into the flank for about 12 to 15 cm. When the peritoneum is traversed, the patient is placed in a moderate Trendelenburg position, the small bowel is carefully packed into the upper abdomen, and the posterior peritoneum is incised over the terminal aorta and reflected to expose the terminal aorta and the first few centimeters of the iliac arteries. The terminal aorta is separated from the adjacent structures by careful dissection and a narrow tape is passed around it. Special care must be exercised to avoid injury to the vena cava, which lies just to the right of the aorta. A small section of gauze, rolled into a ball and grasped in a curved clamp, is especially satisfactory for this type of dissection. The common iliac arteries are then freed up and tapes are passed around each of them. The mid-sacral artery should also be occluded. The embolus, which is easily palpable, should be carefully outlined and the incision in the aorta should be centered over it. Should the terminal aorta be sclerotic, the incision may be made in one or the other iliac arteries and the embolus milked out through that opening. When the embolus has been removed, the obstructing tapes should be alternately momentarily relaxed to flush out any remaining fragments of clot. This may be unnecessary if the clot is smooth and symmetrical. One tape is relaxed, say on the aorta, while the other two are kept tightened. Then the one that has been relaxed is tightened and another is relaxed. After it is certain there is no further clot present, the incision is closed by a continuous everting mattress suture of four 0 silk on an atraumatic needle. The aortic tape is then relaxed and, if there is no bleeding, the tapes are removed. Should there be appreciable seepage, a few interrupted sutures are placed to control it The peritoneum is carefully closed over the area of the vascular incision. The iliac arteries are now examined to be certain there are no other sites of obstruction. It is wise to have an assistant expose the feet and legs at this time. If they are still cold and pale, and the pulse thready (in the presence of a satisfactory blood pressure and pulse in the upper extremities), it may be wise to interrupt rapidly both lumbar sympathetic chains. The abdomen is closed in the usual way Embolectomy should always be performed by a direct approach when possible. For example, attempts at removal of clots from the aortic bifurcation by passing especially designed probes or suction tubes up from the common femoral or external iliac arteries is unwarranted unless the patient's general condition is such that a direct approach would be extremely hazardous.

This method of electrothermic coagulation is most successfully used in sacculated aneurisms, but Blakemore has used it in somewhat modified form in the arteriosclerotic aneurisms of the distal portion of the abdominal aorta.

LIGATION AND COMPRESSION

Many attempts have been made to cure aneurisms of the abdominal aorta by ligation, but with little success. Proximal ligation alone can hardly be expected to cure aneurisms, although it may give relatively prolonged relief from pain, the result of the compression or erosion of adjacent structures. The difficulty lies in the fact that the maximum effect on the aneurism is obtained only so long as the collateral circulation is relatively inadequate. Once the collateral circulation has become fully reestablished, the pressure within the aneurism sac is restored sufficiently to cause it to enlarge again and to produce symptoms. Even proximal and distal ligation usually will not produce a permanent cure, because the collaterals entering the aneurism sac dilate and lead to recurrence. Ligation should therefore be resorted to only under circumstances which do not permit the performance of curative procedures.

The principle of the gradual occlusion of arteries added greatly to the safety of treatment of aneurisms of certain arteries. It occasionally is employed as a definitive measure, but its chief value is due to the development of the collateral circulation from diminution of the lumen of the main artery. This method of increasing the collateral bed was first recommended by Halsted, who used aluminum bands with smooth edges. These bands were placed around the artery and curled into position by a special device. Later the bands were modified by Matas, who occluded the vessel by flattening the band rather than curling it. Reid adopted the Matas method of applying these metal bands because he believed there was less danger of injury to the wall of the artery. The bands vary in width from 3/16 to 5/16 inch and are about as thick as sheet metal gauge No. 23, or 0.6 mm.

In some interesting experimental work Halsted (1918) found that there frequently was dilatation of the vessel on the distal side of the band which was difficult to explain, but he thought it might be due to an eddy or whorl in the partially obstructed current. The most likely explanation is that the band interferes with the nutrition of the vessel wall, not only that portion under the band but also that immediately distal to it.

In the treatment of aneurisms of the extremities it is important to develop the collateral circulation to as great an extent as possible before an attempt is made to excise the sac or to obliterate it. This may be hastened by the local application of heat in the form of hot packs or, better still, diathermy. Proximal compression of the artery by digital pressure or by a special apparatus is also valuable. Compression is one of the oldest methods of treating aneurisms and, while various appliances and ingenious methods have been used, they have not been any more satisfactory than digital compression This must be done at first by the surgeon or a well-trained assistant, but if the patient is intelligent and the vessel to be compressed is in a location which he can easily reach, the treatment may soon be turned over to him. The femoral artery below Poupart's ligament and the common carotid artery are among the most favorable locations for digital compression.

Elastic compression has been applied by bandaging the limb with an elastic bandage up to the aneurism and then skipping the aneurism and bandaging the limb above it. In this way the blood was shut off above and below the aneurism and clotting often occurred. However, this procedure proved too dangerous and was discarded.

Extreme flexion also was formerly used in the treatment of aneurisms develop- g in the popliteal region, in the groin, or in the elbow. It consisted of forced xion which had to be maintained for a number of days. It was of course exceed- ly painful and cured only an occasional case, so it too was discarded. Compres- 1, no matter how applied, is now used only as a means of stimulating the develop- it of the collateral circulation.

The most certain and altogether the most satisfactory way to ensure an adequate collateral circulation is by preliminary section of the sympathetic nerves to the collateral area.

The adequacy of the collateral circulation may be tested preoperatively by the method suggested by Matas. A snug Esmarch bandage is applied from the distal part of the limb to the trunk. The main artery is then compressed, the Esmarch bandage removed, and note is made of the returning circulation which must be carried by collateral channels. In the thigh a hyperemic flush extends quickly to the knee but may go much more slowly or not at all to the foot. If the flush does not reach the ankle, operation should be postponed and treatment continued until a satisfactory collateral bed has been established. The value of this test is limited since it is not applicable to the dark-skinned races.

If doubt remains as to the adequacy of the collateral bed, the artery should be exposed proximal to the aneurism and the lumen should be carefully occluded either by a metallic band or by a strip of fascia. In carrying out this procedure it is desirable to leave a very small opening so as to avoid injury to the wall of the vessel, especially to the intima It is usually desirable to tie the vein at the time the artery is occluded. The operation should be carried out under local anesthesia when the carotid artery is involved, otherwise the symptoms and signs of cerebral anemia may be confused with the aftereffects of a general anesthetic, as in a case reported by Reid. If evidence of insufficient collateral circulation should develop, the arterial obstruction may be released, with excellent prospects of an immediate satisfactory flow of blood through the main channel. If the collateral circulation proves to be adequate, the surgeon can proceed with the excision or obliteration of the aneurismal sac. The above procedure is especially indicated in aneurisms of the carotid, the common femoral, the popliteal, and the axillary arteries.

Many of the classical methods of using the ligature for the cure of aneurism are now only of historical interest The operation of Antyllus has been used for the cure of aneurisms since the second century of the Christian Era and still is of some value in selected cases It consists of ligating the artery close to the aneurism, both centrally and distally, and then incising the sac (Fig. 40). In preantiseptic days the suppuration following this method gave a high mortality but the percentage of cures was gratifying.

Anel's method, first used in 1710, consists in ligating the artery proximally as close as possible to the sac (Fig 41). In preantiseptic days when suppuration was the rule, secondary hemorrhage was frequent. It was thought that this was partly due to the fact that the artery near the sac was diseased; so Hunter in 1785 estab-

lished the new principle of applying the ligature at some distance proximal to the aneurism (Fig. 42). In this method important collateral branches are given off from the section of the main artery between the ligature and the aneurism and are therefore unable to function. Hunter's operation is still used occasionally but has many disadvantages, and his assumption that the artery was less diseased at a distance from the aneurism than close to it is by no means always true. The liability to gangrene also is increased, because if the sac is occluded by clot there will be two obstructions to the current instead of one, that at the site of ligature and the other distally at the aneurism sac. The collateral circulation is thereby greatly diminished, for the blood has to pass through two sets of collateral branches, those arising

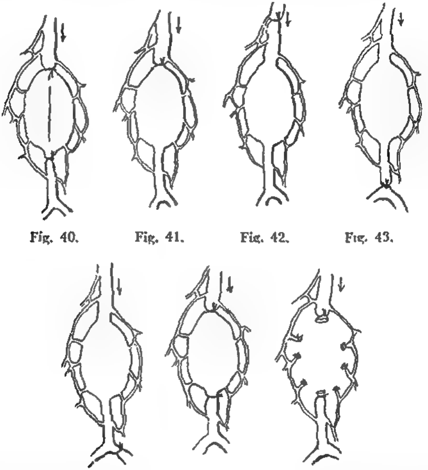


Fig. 40. Fig. 41. Fig. 42. Fig. 43.

Fig. 44. Fig. 45. Fig. 46.

Fig. 40.—The operation of Antyllus for aneurism.
Fig. 41.—The operation of Anel.
Fig. 42.—The operation of John Hunter
Fig. 43.—The operation of Brasdor.
Fig. 44.—The operation of Wardrop
Fig. 45.—The operation of Pasquin.
Fig. 46.—The operation of Purmann

proximal to the ligature and those arising distal to the ligature but proximal to the sac. If, on the other hand, the collateral circulation is free, the aneurism may not become filled by clot and no benefit will result. Anel's operation, therefore, is superior to Hunter's except in occasional instances where infection develops in the tissues adjacent to a recently acquired false aneurism. Under such circumstances Hunter's operation may be the procedure of choice.

Brasdor instituted the method of distal ligation in 1798 (Fig. 43), and Wardrop, in 1825, applied ligatures distally to one or two of the main branches of an

artery (Fig. 44). This was used in aneurism of the innominate where the carotid artery was often tied. The application of ligatures immediately above and below the aneurism without opening the sac is called Pasquin's operation, which was first used in 1812 (Fig. 45).

Ligation proximally and distally close to the aneurism with extirpation of the sac has been known as the operation of Purmann, who used it in 1680 (Fig. 46). For this procedure it is necessary to have complete hemostasis, and in the extremities this is best obtained by a tourniquet, because large collateral vessels open into the sac and both central and distal ligatures may fail to control hemorrhage.

In all operations upon aneurisms careful hemostasis is essential, so all vessels of appreciable size immediately in the line of incision must be clamped and ligated as the operation proceeds. On the other hand, important collateral vessels should be carefully protected. After a tourniquet is removed, all bleeding must be controlled with care, for the development of a large hematoma may lead to disaster, either as the result of postoperative infection or the clot may cause sufficient pressure on the surrounding tissues to interfere with the collateral bed. Unless contraindicated, fine silk ligatures should be used, for they produce less tissue reaction and less swelling than ligatures of most other materials.

Proximal and distal ligation with extirpation of the sac is in some respects an ideal method of treatment for aneurisms, but it has a number of serious disadvantages. It is a laborious, time-consuming procedure and may be practically impossible of execution. It also interferes to a greater extent with the collateral circulation than some other methods of treatment. However, excision of the sac, followed by reestablishment of the arterial channel by vein graft, has much to recommend it. So does the use of inlay vein grafts as described by Blakemore.

MATAS OPERATION

One of the great advances in the treatment of aneurisms is the operation of Matas, first performed by him in 1888, on a brachial aneurism that had not been cured by both proximal and distal ligation. The Matas operation may be performed in three ways, though the principle is essentially the same in all three. They are obliterative endoaneurismorrhaphy, restorative endoaneurismorrhaphy, and reconstructive endoaneurismorrhaphy (Figs. 47, 48, and 49). Obliterature endoaneurismorrhaphy (Fig 47) may be used in any form of aneurism, but it was designed particularly for cases in which the two openings in the sac are some distance apart and therefore not suitable for repair, or those in which the sac is particularly friable. Hemostasis is obtained by a tourniquet if possible, or, if this is impracticable, by clamps such as those devised by Crile or Matas, or those devised for lateral suture of blood vessels. These clamps are placed on the artery, both above and below the sac, and on its main branches. The sac and adjoining vessel should not be dissected out, so a tourniquet is preferable when one can be used. By bearing in mind the principle on which the operation is founded, conserving every possible collateral branch in the sac and surrounding tissues, the operation can be carried out more effectively. After the tourniquet has been applied, an ample incision is made through the skin over the aneurism. If it is not possible to use a tourniquet, the vessel is exposed proximally and distally near the aneurism and clamps are applied, as mentioned above The sac is then opened without

separating it from the surrounding structures and the clot is removed. Sutures of adequate size on small, round, full-curved needles are passed through the margins of the openings and tied with care, so that they will not cut through. The sac is then searched for openings of collateral arteries and these are also closed. The circulation is released by removing the tourniquet or clamps to demonstrate

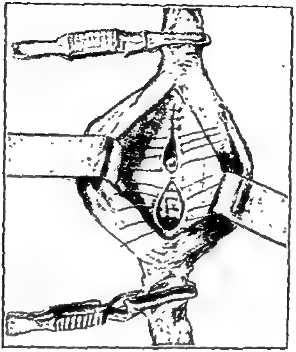


Fig. 47.—Obliterative endoaneurismorrhaphy of Matas.

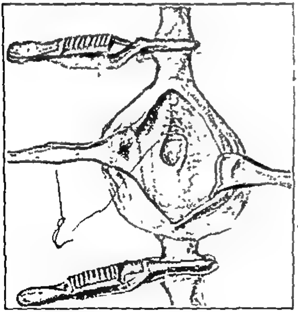


Fig. 48.—Restorative endoaneurismorrhaphy of Matas.

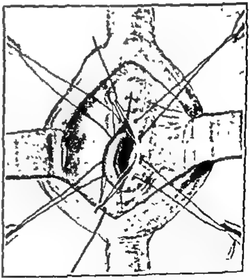


Fig. 49.—Reconstructive endoaneurismorrhaphy of Matas.

whether bleeding from the branches in the wall of the sac has been controlled. If there is no bleeding, the sac is obliterated by rows of sutures, the first row running preferably from one arterial opening to the other. After this has been finished, another more superficial row is placed. The manner of treating the sac after the

two tiers of obliterative sutures have been placed depends largely upon the condition and size of the sac and must of necessity be left to the judgment of the surgeon. The essential features are to close the arterial openings into the sac and to place at least two rows of sutures, obliterating the sac, in so far as possible, from one of the main arterial openings to the other. After this, the recesses of the sac are folded upon themselves, or sutures are carried through a double thickness of the sac and tied in the margin of the wound. All dead space should be obliterated and the wound closed without drainage. The smooth membrane lining the inside of the sac is vascular endothelium and requires no freshening or injury to heal, but merely snug approximation as with the peritoneum. In intraperitoneal aneurisms the peritoneum is so sutured as to cover the raw surface.

Restorative endoaneurismorrhaphy (Fig. 48) is applicable when the sac is tough but pliable and when there is only one opening. In other words, when the aneurism springs from one side of the artery and involves only a small part of the arterial circumference. Such ideal conditions are not frequently encountered but when they are, the opening is sutured in such a way that the arterial lumen is preserved. The rest of the procedure is identical with the obliterative method. Practically speaking, this method is applicable only to traumatic aneurisms.

Reconstructive endoaneurismorrhaphy (Fig. 49) is recommended by Matas in cases in which the sac is tough and holds sutures well. The sac is cleaned of clots and washed out with salt solution. Matas recommended that a soft rubber catheter, well anointed with petrolatum and fitting snugly into the arterial openings, be inserted, and that interrupted sutures be placed at close intervals over the catheter. After the sutures have been placed, the catheter is withdrawn and the sutures are tied. The rest of the sac is obliterated as in the other methods. This method is very rarely applicable.

Reconstructive endoaneurismorrhaphy probably sooner or later either becomes obliterative or fails to cure. The fact that, in several instances, thrombi which formed following the reconstructive operation were later dislodged and acted as emboli is also a serious objection to this method. In experimental work under the best conditions with comparatively healthy blood vessels and using the finest sutures of silk and the finest needles, it is impossible to avoid occasional occlusion of the artery by clot, even after some experience in vascular suture. This being the case, we should not expect sutures used on comparatively coarse needles, in diseased tissue, to produce permanent patency If there is a small single opening between the aneurism and artery, the restorative method is indicated, but the obliterative method is to be preferred to the reconstructive method.

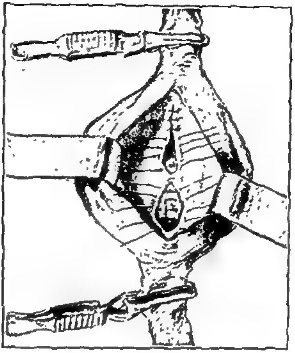
In all methods of aneurismorrhaphy care should be taken to take no deeper bites with sutures than is necessary to secure a firm hold; otherwise, the needle may wound the accompanying vein or a nerve or may occlude collateral vessels.

There seems no doubt that endoaneurismorrhaphy is less likely to cause gangrene than is extirpation.

EXCISION OF SAC

The ideal treatment of aneurisms is to excise the sac and preserve the arterial channel. Extirpation of aneurisms of the popliteal artery followed by direct end-to-end suture of the artery has been done but is rarely feasible, for it is applicable

separating it from the surrounding structures and the clot is removed. Sutures of adequate size on small, round, full-curved needles are passed through *the margins* of the openings and tied with care, so that they will not cut through. The sac is then searched for openings of collateral arteries and these are also closed. The circulation is released by removing the tourniquet or clamps to demonstrate



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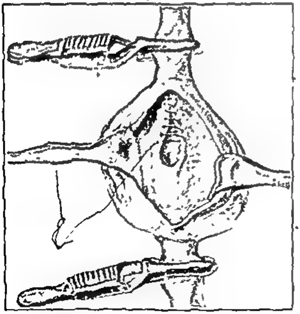

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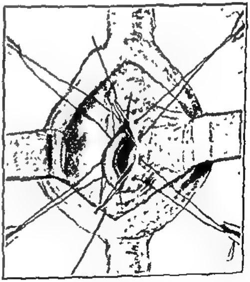

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only when the aneurism involves a short section of the artery and the remainder of the artery must be healthy. Restoration of the channel by substituting a segment of vein for the excised section has much to recommend it and will almost certainly be used more frequently. The vein that accompanies the artery is generally used. In recent years Blakemore and others have reported the successful use of vein implants in the cure of aneurisms. This procedure also has much to recommend it and is applicable under circumstances not suitable for aneurismectomy and grafting.

OPERATIONS ON ANEURISMS OF SPECIAL ARTERIES

Aneurisms of Thoracic Aorta

Aneurisms of the thoracic aorta are the most frequent ones, as would be expected, because of the strain to which this great vessel is subjected. In this location surgical treatment usually is not indicated, though in sacculated thoracic aneurisms wiring by Blakemore's technic may be worthy of trial. Abbott, Poppin, and others recommend the application of polythene or cellophane.

Guinard, of Paris, in 1904 attempted to cure an aneurism of the thoracic aorta by proximal ligation; the chest was opened posteriorly by an osteoplastic flap and a ligature was placed on the thoracic aorta just below the arch. When the ligature was tightened, pulsation in the femoral arteries stopped and the lower part of the body became pale and cold, but in a few minutes the circulation was partially reestablished. However, the pressure was not sufficient to maintain renal function and the patient died. It is likely that this will practically always be the result of primary complete occlusion of this portion of the aorta, and that almost the only hope of successfully treating aneurisms of the thoracic aorta by surgery is by the use of grafts; after excision of the aneurism or more likely by using Blakemore's technic of inlay grafting.

The average duration of untreated thoracic aneurisms is a little more than a year.

Aneurisms of Abdominal Aorta

Aneurisms of the abdominal aorta, especially those above the level of the renal arteries, are infrequently amenable to treatment other than by the Blakemore method of wiring. Even this procedure has a limited scope, for aneurisms above the renal arteries involving the superior mesenteric artery or the celiac axis will in all probability result fatally if obliterated by any means. Unless aneurisms of the proximal portion of the abdominal aorta are distinctly sacculated, with a small communication with the aorta, which can be closed with preservation of the lumen of the aorta and its essential branches, the outlook is poor. In aneurisms below the renal arteries, the outlook is more hopeful, but the results so far have not been good Methods must be used which will permit extirpation or obliteration of the aneurism sac, yet maintaining adequate circulation to the lower extremities before the treatment of abdominal aortic aneurisms can be more than palliative. Excision and the insertion of grafts or the use of inlay grafts offer the greatest hope.

In the very small number of sacculated traumatic aneurisms of the aorta it is possible to do a restorative aneurismorrhaphy.

We have in one instance resected the aorta from just below the origin of the renal arteries to its bifurcation, and now, six years later, there is nothing to suggest the development of other aneurisms and the patient's general health is satisfactory, but she is still partially disabled by weakness of the lower extremities, the result of severe ischemic neuritis, which followed occlusion of the aorta. This case is cited to show that at least in some instances removal of aneurisms of the distal aorta is feasible and may give prolonged relief. Efforts to cure such aneurisms will be altogether justifiable if it is possible to remove the aneurism and yet maintain an adequate circulation to the lower extremities.

Involvement of the inferior mesenteric artery apparently does not contraindicate excision or obliteration of an aneurism sac, a matter of considerable importance since that artery is involved in a large percentage of aneurisms of the distal aorta.

Blakemore's technic for inlay vein grafts is to gain control of the circulation above and below the aneurism, open the sac, evacuate the clot, and close all collaterals entering the sac, much as is done in the Matas obliterative endoaneurismorrhaphy. He then takes the segment of vein to be implanted, passes the ends through his special Vitallium cannula, turns the ends back over the cannulae, and fastens them by silk ligatures tied back of the ridges or shoulders on the cannulae. The ends are then fitted into the openings of entrance and exit of the main artery and fixed in place by silk sutures These sutures are inserted through the wall of the artery at its junction with the aneurism, then through the cuff of vein, and finally through the opposite arterial wall, fixing the graft in place. The vein for inlay is not cut until the distance between the openings of entrance and exit is determined. Blakemore then adds 4 cm. to that distance for the proper length of the venous transplant. This procedure appears to be well adapted for use in aneurisms of the distal abdominal aorta.

Innominate Aneurisms

True innominate aneurisms are apt to be amenable to radical surgery, but unfortunately many so-called innominate aneurisms are in reality aneurisms of the aortic arch, arising at the origin of the innominate artery. Surgery is naturally less satisfactory in this latter group of cases. Occlusion of the innominate artery is always a serious undertaking, but the risk increases with age, so in patients of middle age or older, all available measures for increasing the collateral blood flow should be employed Since sympathectomy is the most important of these measures it should be done as a preliminary procedure. The greatest danger from occlusion of the innominate artery is marked ischemia of the central nervous system. Occlusion of the common carotid artery by fascia preliminary to direct attack on the aneurism is therefore advisable. Fortunately, extirpation of the stellate and the second and third dorsal ganglia and occlusion of the proximal common carotid are readily done through the same approach. If there is no adverse reaction to occlusion of the common carotid, one may attack the aneurism with reasonable assurance that the blood supply to the right upper extremity will be adequate.

In the direct attack on the aneurism it is essential that the exposure be altogether adequate, otherwise it is unlikely that the operation will be successful. Provision must be made for exposure of the bifurcation of the innominate, the entire aneurism, and the origin of the innominate from the arch of the aorta. This prob-

ably is best accomplished by resection of the medial portion of the clavicle and by splitting the sternum from the jugular notch to the level of the third intercostal space. This approach is recommended by Shumacker, who apparently has found it very satisfactory.

Traumatic aneurisms of the innominate artery may be amenable to restorative aneurismorrhaphy, and some spontaneous innominate aneurisms may be cured by obliterative endoaneurismorrhaphy, but extirpation of the aneurism usually is the procedure of choice. When an adequate exposure has been obtained, the problem should be evaluated by a careful examination of the origin of the innominate from the aortic arch and the relationship of the aneurism to adjacent important structures such as the innominate veins and the vena cava, to the trachea, the vagus nerves, etc. If resection of the aneurism is decided upon, it is advisable to section the carotid and subclavian arteries between ligatures as the first step. Additional suture ligatures should be applied to the distal segments of both these vessels. Primary occlusion of these vessels is recommended because manipulation of the aneurism incident to separating it from the adjacent structures may force some of the clot lining the sac out into these vessels, with disastrous results. After the carotid and subclavian arteries have been occluded, attention should be turned to the base of the innominate. If the origin of the innominate is greatly widened, ligatures will likely cut through. A wide strip of fascia lata wrapped around the base of the artery at least twice, then fixed by several silk sutures, is probably as safe a way as any to occlude a large communication between the aorta and innominate artery. After the communication with the aorta has been closed, the aneurism sac may be more readily and safely separated from the adjacent structures. Ligation of one of the innominate veins, preferably the right, is almost certain to be necessary. Although division of the left innominate vein between ligatures permits somewhat better retraction of the superior vena cava, it is obviously desirable to occlude the vein on the side of the arterial occlusion if possible. If, for any reason, removal of the entire sac is not feasible, a strong clamp may be placed across the sac well above the strip of fascia, and the sac may then be opened and evacuated. The closure by the fascial strip may then be reinforced by interrupted mattress sutures of silk. If the arterial wall at the base of the innominate seems in good condition, one might apply an occlusive clamp, then apply sutures somewhat as in closure of the divided ductus arteriosus Blakemore apparently has used the latter method of closure with satisfaction in at least one instance.

Carotid Aneurisms

In carotid aneurisms, preliminary proximal fascial occlusion of the artery, as advised in innominate aneurisms, is recommended. In case occlusion by fascia produces no evidence of cerebral ischemia, a curative operation should be undertaken within a few weeks, for fascial strips may soon give way. The problem is not an easy one to decide upon, for the majority of carotid aneurisms occur near the bifurcation of the common carotid, and, if they are large, it is difficult to expose either the external or internal carotids above the aneurism, especially the latter vessel Excision is therefore almost certain to be difficult, and in addition there is danger of interference with the cerebral circulation because of occlusion of both the external and the internal carotids.

We have treated a number of aneurisms in the region of the bifurcation of the carotid by preliminary fascial occlusion of the common carotid, followed within a few days to a few weeks by obliterative endoaneurismorrhaphy. The results have been satisfactory in all except one. In this instance, a fifty-eight-year-old man who had had two previous cerebral vascular accidents, one of them more than two years before the aneurism was first noticed, developed hemiplegia following the aneurismorrhaphy. The fascial occlusion was done as an emergency because of necrosis of the skin over the most prominent portion of the aneurism. There was no evidence of cerebral ischemia and the occlusion seemed to be complete for six or seven weeks. Unfortunately the fascia gave way at this time and bleeding recurred. Obliterative aneurismorrhaphy was performed but required more than the usual amount of manipulation, since the arterial defect involved the posterolateral surface of the vessel at the bifurcation. The operation was done under regional and local anesthesia and during the manipulation of the sac the patient showed incoordinated muscular contractions, then shortly lapsed into unconsciousness. Later he was found to have a hemiplegia. It is likely that manipulation of the aneurism forced a fragment of clot into the internal carotid. In spite of this untoward result, we feel that obliterative endoaneurismorrhaphy is the procedure of choice in the treatment of most aneurisms near the bifurcation of the common carotid artery.

Aneurisms of the external carotid are rare but do occasionally occur. In the past, the majority of them have been treated by proximal ligation alone, probably because of the difficulties encountered in their obliteration or excision Preliminary proximal ligation, with division of the artery, is of value, for the aneurism will shrink temporarily, making excision or obliteration of the sac less difficult. Aneurisms of the common carotid or of the internal carotid arteries are of grave significance because of the disastrous effect on the brain that often follows when one of these arteries is occluded. In young patients with elastic arteries ligation of the common carotid is comparatively safe, but in later life, particularly when there is advanced arteriosclerosis, cerebral symptoms frequently occur after occlusion of the internal carotid or common carotid arteries. It has been found that when cerebral symptoms do occur, prompt reestablishment of blood flow through the obstructed artery usually is effective in preventing permanent central nervous system changes Fortunately it usually is possible to detect quite early evidence that the blood supply to the brain is inadequate. It is therefore important to do a preliminary occlusion by a method which is reversible, before permanently obstructing the common or internal carotid arteries The artery, usually the common carotid, should be exposed under local anesthesia and subtotally occluded, preferably by a strip of fascia (Fig. 50) or by a Halsted metal band. Local anesthesia is used so that early symptoms of cerebral ischemia will not be confused with the effects of general anesthesia. If cerebral symptoms develop, the occluding fascia or band must be removed at once. If no adverse symptoms develop, permanent occlusion should be done within a few weeks This is especially indicated if fascia is used, since occlusion by fascia frequently is spontaneously released after a matter of weeks Cerebral symptoms sometimes appear after several days though they are usually manifest within less than twenty-four hours. Even when evidence of

cerebral ischemia is noted only after several days, the fascia or band still should be removed, for there still remains a reasonable chance that the circulation will be reestablished. If subtotal occlusion is not borne well, one should consider the advisability of excision of the aneurism and the use of a vein graft or the use of an inlay vein graft as described by Blakemore.

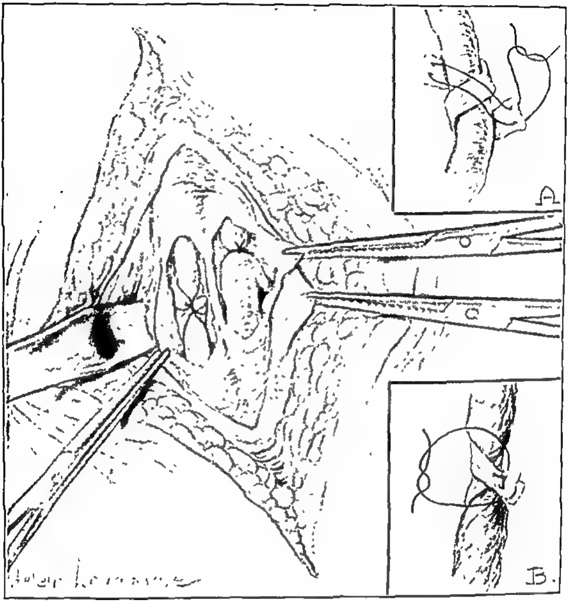

Fig. 50.—Use of strip of fascia lata for occlusion of an artery Note that the vein has been ligated *A* and *B*, Method of application of fascia.

Subclavian Aneurisms

The treatment of subclavian aneurisms depends upon a number of factors: the size of the aneurism, the portion of the artery involved, whether on the right or left side, and the age and general condition of the patient.

Aneurisms of the first part of the right subclavian artery usually will require resection of the medial end of the clavicle and section of the upper part of the sternum Large aneurisms of this portion of the right subclavian artery present many of the problems presented by innominate aneurisms and require essentially the same approach and treatment. Proximal occlusion usually will be somewhat less of a

problem, but, in the presence of a large sac, even this may be little different from innominate aneurism. Endoaneurismorrhaphy is at times feasible and should be used when it is possible to do so, for it may enable one to save some of the very important collateral vessels such as the vertebral artery, the internal mammary artery, and the thyrocervical axis. Aneurisms of the left subclavian artery usually present the same problems and require the same treatment as those on the right side, but when they occur near the origin of the artery from the arch of the aorta, a transpleural approach through the left second interspace may make it possible to occlude the artery proximal to the sac with somewhat less difficulty. Resection of a portion of the clavicle usually will be necessary in order to gain control of the circulation distal to the aneurism

Aneurisms of the distal part of the subclavian artery and the proximal section of the axillary artery usually require extensive resection of the clavicle. One of the principal difficulties encountered in connection with aneurisms in this area is involvement of the cords of the brachial plexus. In traumatic aneurisms the cords of the plexus are frequently injured, and in spontaneous aneurisms they may be severely damaged by the expansile pressure of the aneurism The close relationship with these large nerve trunks makes wide exposure and complete hemostasis altogether necessary. Small aneurisms in this area probably are best treated by excision; large ones may be best handled by obliterative endoaneurismorrhaphy. However, if there has been primary nerve injury, excision of the sac may be obligatory for exposure of the injured nerves.

In subclavian and axillary aneurisms sympathectomy is advisable, preliminary to or at the time of operation on the aneurism.

Aneurisms of the distal part of the axillary artery or of the proximal segment of the brachial artery may be treated by endoaneurismorrhaphy or by extirpation of the sac. In certain traumatic aneurisms reconstructive aneurismorrhaphy is feasible and is the operation of choice When the axillary artery is occluded, it is advisable to occlude the axillary vein

Iliac and Femoral Aneurisms

The treatment of aneurisms of the common iliac arteries has much the same dangers as does the treatment of aneurisms of the terminal aorta, for the common iliacs are only a few centimeters in length, so before one can excise or obliterate the sac it is often necessary to occlude the terminal aorta In aneurisms of the internal iliac arteries, especially those arising near the bifurcation of the common iliacs, it is necessary to expose and temporarily occlude the common iliac, the external iliac, and the opposite internal iliac Either excision or obliterative aneurismorrhaphy should prove satisfactory. The ureter is almost certain to be involved by scar, so it should be exposed proximally and distally if the aneurism is to be excised Left iliac aneurisms are somewhat more difficult because of the proximity of the branches of the inferior mesenteric artery. They should be exposed and protected.

Preliminary proximal occlusion by fascia may be helpful in iliac and common femoral aneurisms. Lumbar sympathectomy should be done at the time of the fascial occlusion. Testing the efficiency of the collateral circulation and performing sympathectomy preliminary to definitive operations for aneurisms are always sound

measures, but they are especially indicated when aneurisms involve the common and internal carotids, the common iliacs, the common femorals, and the popliteal arteries.

Since aneurisms of the iliac arteries are supported anteriorly only by peritoneum, they tend to enlarge rapidly and are more prone to rupture than are aneurisms surrounded by muscle and fascia. Iliac aneurisms should therefore be operated upon promptly.

Fig. 51.

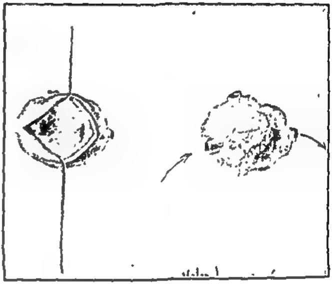

Fig. 52.

Fig 51.—Traumatic aneurism of the superficial temporal artery.

Fig 52.—The excised sac of the traumatic aneurism shown in Fig. 51. Note the afferent and efferent vessels.

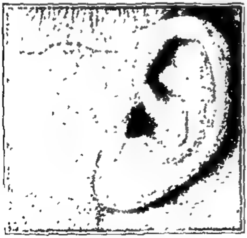

Fig 53.

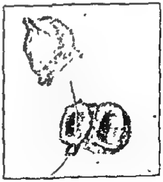

Fig. 54.

Fig 53—The second case of traumatic aneurism of the superficial temporal artery.

Fig 54—Drawing of the excised sac shown in Fig 53.

It is exceedingly difficult to obtain satisfactory hemostasis during operations upon aneurisms of the common femoral artery without temporary occlusion of the external iliac artery. This is best accomplished through an extraperitoneal approach. The number of important collateral vessels in this area, including the profunda femoris artery, makes excision of the aneurism sac hazardous. Endoaneurismorrhaphy usually is the operation of choice. If extirpation of the aneu-

rism is undertaken, the surgeon should be prepared to reestablish the continuity of the femoral artery by vein graft.

Aneurism of the superficial femoral artery may be treated satisfactorily by obliterative endoaneurismorrhaphy or by excision of the sac, if the important collateral vessels are carefully protected.

Popliteal Aneurisms

Popliteal aneurisms are said to comprise about one-third of all spontaneous aneurisms other than those arising from the aorta. In the treatment of aneurisms in this area extirpation of the sac should be done only if the surgeon is prepared to maintain the continuity of the popliteal artery by vein graft. Also it is important that a preliminary lumbar sympathectomy be done. When combined with sympathectomy, obliterative endoaneurismorrhaphy usually gives satisfactory results. Incisions for the exposure of popliteal aneurisms may be made transversely or in the form of an S, but straight incisions directed perpendicularly across the popliteal crease are inadvisable as they lead to contractures at the level of the crease.

Popliteal aneurisms may involve the whole of the artery in the later stages, but in the early stages they are often of the saccular form in which a very small portion of the artery is affected. Under such circumstances it may be possible to excise the aneurism and unite the ends of the artery by suture. Operations upon aneurisms arising in the upper part of the popliteal space are less likely to be followed by ischemic gangrene than upon those arising in the lower portion of this space.

Aneurisms of Smaller Arteries

Aneurisms of the smaller arteries, such as the radial, ulnar, or tibial arteries, usually are best treated by proximal and distal ligation of the artery and extirpation of the sac. The circulation from the companion artery usually is abundant and hemorrhage can be controlled by tourniquet, so excision of the aneurism is safe and the most certain means of cure. Aneurisms of such vessels as the superficial temporal artery also are best treated by excision (Figs 51, 52, 53, and 54).

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CHAPTER 10

ARTERIOVENOUS FISTULAS

QUADRUPLE LIGATION AND EXCISION; TRANSVENOUS ARTERIORRHAPHY

I. A. Bigger

An arteriovenous aneurism or fistula is a lesion in which there is an abnormal communication between an artery and a vein. Two forms of arteriovenous aneurisms are described: varicose aneurism, in which the communication between the artery and vein is indirect in that a sac exists between the two vessels; and aneurismal varix, in which the blood flows directly through an opening from the artery into the vein. There are many combinations: There may be a sac involving the wall of the artery opposite the communication with the vein, or there may be two sacs, one communicating with the artery alone and one between the artery and vein. Also there may be a sac involving the wall of the vein opposite the fistula Both vessels become dilated proximally, unless the parts around them form a rigid support.

The most frequent cause of arteriovenous aneurism is direct trauma, bullet wounds and stab wounds being the cause of most of them The penetration of large contiguous vessels, such as the femoral artery and vein, is particularly apt to be followed by a persistent fistula between them. Formerly, when blood letting was in vogue, arteriovenous aneurism between the brachial or the ulnar artery and a vein was comparatively frequent. Elkin has called attention to the development of arteriovenous fistulas following surgical trauma. Fractures or indirect injuries rarely result in arteriovenous aneurism The spontaneous development of a fistula between an artery and vein is also rare and is probably always due to degeneration in the wall of the artery; as, for example, when an aneurism perforates into an adjacent vein

Because of the activity of the circulation in the vicinity of arteriovenous fistulas, the result of the great difference in pressure between the arterial and the venous trunks, clots rarely form and the prospect of spontaneous cure is slight. The liability to rupture depends to some extent upon the size of the sac but is mainly dependent upon the character of the surrounding tissues. An aneurismal varix rarely ruptures.

That portion of the artery distal to a fistula usually decreases in size as it has to carry a smaller volume of blood than normal Some of the blood passes through the fistula to the vein and is returned directly to the heart. The proportion of arterial blood entering the vein through the fistula is dependent upon the size of the opening, for through the fistula into the vein and back to the heart is the path of least resistance. The proximal segment of the artery usually is dilated.

This was formerly supposed to be due to atrophy of its walls but is now believed to be due to the large column of blood which it must carry; for not only must it furnish blood to the parts distal to the fistula but it must also supply the abnormal communication between the artery and vein. As Holman has pointed out, the segment of artery distal to the fistula may become dilated if for some reason it is impossible for the proximal segment to dilate. This also is due to the passage of a larger volume of blood which here comes through collateral channels, entering the artery distal to the fistula. The fistula creates a path of lessened resistance and when the blood passing through the undilated segment of artery is not sufficient to supply the demands of this abnormal channel, that blood entering the main artery immediately distal to the fistula is drawn back and returns to the heart by way of the fistula. The vein also is dilated, distally as far as the first valve and centrally as far as the vena cava or even the heart. The wall of the vein gradually thickens and becomes more like the wall of an artery; in long-standing cases it may be difficult to distinguish the proximal segment of the vein from the artery. Sometimes in the large veins immediately distal to the fistula the function of the valves is destroyed by the increase in pressure of the blood in that area. This, in turn, may cause swelling and further interference with the circulation to the tissues distal to the fistula. Nutritional disturbances in the form of ulcers or even gangrene may appear because too little blood reaches the arteries distal to the fistula. The degree of local disturbance depends upon the location as well as upon the size of the arteriovenous communication. A small fistula will cause but little disturbance, whereas a large one may lead to rapid tissue changes from impaired nutrition

A large opening between large vessels may so greatly increase the volume of blood to the heart that a rapid dilatation of the heart ensues. That the early change in the size of the heart is due chiefly to dilatation is shown by its rapid return to normal or near normal upon closure of the fistula. Fistulas of long duration are apt to produce both cardiac dilatation and hypertrophy.

The signs of an arteriovenous aneurism may appear immediately after the injury or after the lapse of some days or even weeks Usually the clots and the edema in the adjacent tissues will reduce the size of the communicating channel for several days and thus obscure the picture

Most surgeons who have had considerable clinical experience with arteriovenous aneurism have felt that it is better not to operate upon the majority of such cases for several weeks or even several months unless the patient is seen immediately after the trauma If there is rapid cardiac dilatation or evidence of insufficient blood supply distal to the lesion, early operation becomes necessary. If the patient is not seen immediately after the injury, and none of the indications for early operation is present, he is put at rest to protect the heart and to aid the circulation distal to the fistula. Conservative treatment may be continued for two or three months, to allow time for the swelling in the tissues adjacent to the fistula to subside and for all the bacteria in the damaged tissues to be destroyed, as well as for the development of the collateral circulation The presence of a fistula between an artery and a vein is a tremendous stimulus for the development of the collateral bed, and Bosher has shown that collateral development is far more rapid than was formerly thought.

If the condition is recognized at once and the attending circumstances are satisfactory, it would seem best to operate as soon after the injury as possible. In immediate operations the vessels should be sutured according to the technic described in the chapter on suturing blood vessels Unfortunately, most of these cases occur in military surgery or in civil practice under circumstances which do not permit such treatment. If operation cannot be done within a few hours after the injury, it is better to postpone it for several weeks because of the danger of infection and also because the changes in the tissues, including the walls of the vessels, make it difficult to do a satisfactory repair. One disadvantage of prolonged con-

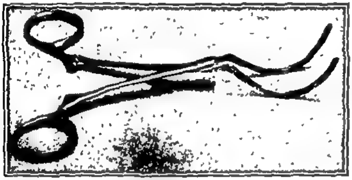

Fig. 55

Fig. 56.

Fig. 55.—Horsley's forceps for lateral blood vessel suturing.
Fig 56.—Method of applying the forceps.

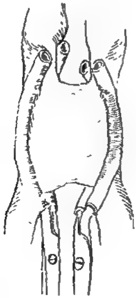

Fig 57

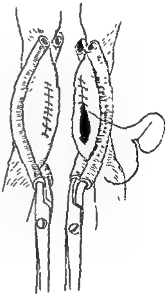

Fig 58

Fig. 57—The vein and artery have been occluded with the forceps and the communication is about to be severed

Fig. 58—The communication between the artery and vein has been severed and the openings in the vessels are being sutured.

servative treatment is the fact that the scar tissue may render the vessel walls tough so that they are difficult to penetrate with fine arterial needles. In fistulas of very long standing, the walls of the vessels immediately adjacent to the fistula may even show considerable calcification.

Ligation alone has not proved satisfactory in the treatment of arteriovenous fistulas. Proximal ligation of the artery alone frequently leads to gangrene, so this procedure is absolutely contraindicated. Distal ligation alone can only do harm.

Fig 59.—Arteriovenous aneurism involving the left femoral artery and vein, near the inguinal ligament.

Proximal ligation of the artery and vein is sometimes indicated (Fig. 50), as, for example, when infection develops shortly after the injury, giving rise to the danger of serious hemorrhage. Under such circumstances ligation of both vessels proximal to the field of infection may be necessary, but this should not be expected to cure the fistula *Quadruple ligation, tying the artery and vein both proximally and distally with extirpation of the fistulous area, is the most certain means of obtaining a cure*, and after a lapse of a few weeks this operation can be carried out with

little fear of acute ischemia in the tissues distal to the fistulous area. A possit exception to this rule is found in carotid artery-internal jugular vein fistulas.

However, while the presence of a fistula for a few weeks or months almc assures an adequate collateral circulation for the time being, it does not avo the danger of chronic circulatory deficiency developing after excision of the fistulo area with interruption of the main artery. This development is especially notic able when the main artery to a lower extremity is occluded. Bigger, Herringma and Rives, Blakemore, and Freeman have been impressed with this development

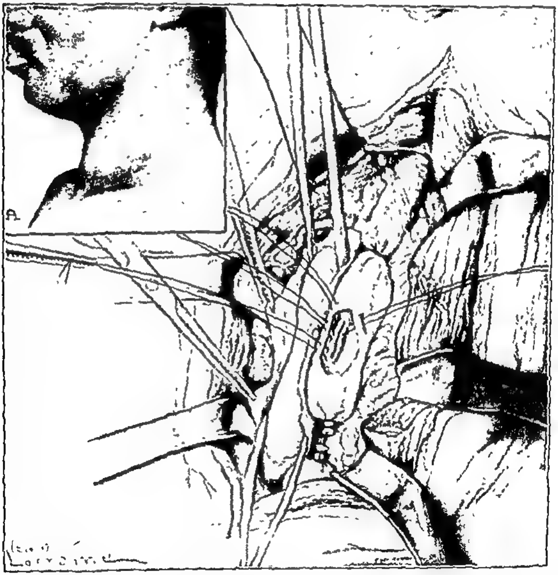

Fig 60.—Transvenous arteriorrhaphy in fistula between common carotid artery anc internal jugular vein The vein has been ligated above and below the fistula and the artery temporarily occluded by tapes

patients. Bosher and Bigger have shown in experimental animals that excision of the fistula is followed by a decided and relatively rapid regression of the collateral bed. It seems desirable, therefore, to preserve main stem arteries, especially those to the lower extremities, whenever it is possible to do so.

Theoretically, the ideal treatment is restoration of the lumen of both artery and vein, but it is doubtful whether preservation of the lumen of the vein is of sufficient importance to justify the increased danger of embolism which this entails

However, if it is possible to secure complete hemostasis, some surgeons prefer to dissect free the artery and vein and to suture the wound in each vessel (Figs. 55, 56, 57, and 58). This, of course, is permissible only when the tissues around the wounds in the vessels are in good condition, without calcium deposits or excessive scar tissue (Fig. 59).

The operation described by Matas, transvenous repair of the arterial opening, is the procedure of choice in many cases. The technic for this operation as evolved by Matas and Bickham is relatively simple when it is possible to obtain complete hemostasis. The vein is opened opposite the fistula and the opening in the artery is sutured with fine silk on curved needles as in restorative endoaneurismorrhaphy. The vein is ligated above and below the lesion, and the walls of the intermediate venous segment are sutured in layers as a reinforcement over the arterial suture line (Figs. 60, 61, and 62).

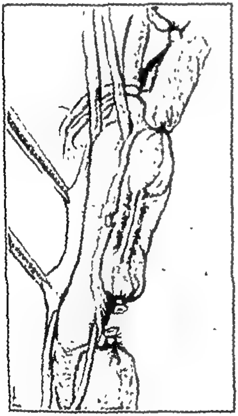

Fig 61.

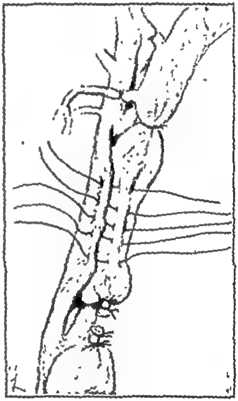

Fig 62.

Fig. 61.—Transvenous arteriorrhaphy. Repair of opening in vein.

Fig. 62.—Transvenous arteriorrhaphy. Suture of wall of vein to vascular sheath to add strength to closure

Freeman has devised a method for preservation of the main stem artery which is applicable in some cases which are not suitable for transvenous repair, and which may prove superior to the Matas-Bickham operation in certain cases. Instead of opening the vein for repair of the arterial opening, Freeman dissects the two vessels apart and excises the scarred rim of arterial wall adjacent to the fistula. He then closes the wound transversely. The possibility of difficulty from the slight to moderate angulation of the artery seems remote.

These operations may be carried out under a tourniquet when the lesion is in an extremity, but in certain locations this is obviously out of the question. The

inability to use a tourniquet does not preclude operation, for the vessels very carefully dissected out, both proximal and distal to the fistula, and tem occluded by the application of Crile clamps or by the use of tapes, while th is being done. Operations done under such circumstances are more tedi time-consuming, and absolute hemostasis is necessary as the operation pr The greatest care should be exercised to avoid injury to either of the majo until the danger of serious hemorrhage is obviated by the occlusion of these above and below the lesion.

The treatment of arteriovenous aneurisms is influenced by a number tors: the size of the involved vessels, the size of the communication, the a general condition of the patient, especially as regards the heart, and the dur the fistula at the time operation is considered. The condition of the hea especial importance in patients who have large fistulas between large vess stressed by Holman, the sudden and sometimes marked rise of blood pressur follows occlusion of the fistula may prove too much strain upon a seriousl aged heart. However, the rise of pressure is transient, so the use of certa tively simple measures largely avoids this danger. The vein may be parti cluded proximal to the fistula, then after a few minutes completely blocked. a short time the artery is occluded with distinctly less rise in pressure than have occurred with primary arterial occlusion. Moderate preliminary dehy will accomplish much the same purpose if the rise in pressure is the resul increased blood volume. In case of emergency venesection is advisable.

In addition to the factors just mentioned, the specific vessels involved importance. Fistulas between the common carotid artery and the internal vein apparently do not develop the rich collateral bed found in connectio fistulas between other vessels. For this reason, an especial effort should be to preserve the lumen of the carotid artery. This is done more safely by firs fully isolating the artery and vein above and below the communication, the porarily occluding them by Crile clamps or by tapes. Either the Matas-Bick the Freeman technic may be used, depending upon which seems better sui the particular case.

In the important vessels of the upper extremities the Matas-Bickham procedure may be used, but quadruple ligation of the vessels and excision fistulous area are less likely to give symptoms than would the occlusion of of corresponding size and importance in the lower extremities. When prese of the main stem artery is not feasible, excision of the fistulous area should complished with as little interference with the collateral channels as possible

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CHAPTER 11

VARICOSE VEINS; VENOUS THROMBOSIS; OBSTRUCTION OF THE LYMPHATICS OF THE EXTREMITIES

BENJAMIN W. RAWLES, JR.

VARICOSE VEINS

Varicosities of the superficial veins of the legs often cause great discomfort and result in serious complications. Successful treatment depends on an understanding of the pathophysiologic changes and the application of the proper therapy in each case. *Blood returns from the lower extremities* through two systems, the deep venous system and the greater and lesser saphenous veins of the superficial system (Fig. 63). The great saphenous empties into the common femoral vein of the deep system, and the lesser saphenous into the popliteal vein. In addition, there are communicating veins between the two systems at various levels in the extremities. Blood normally flows upward from the dependent extremity as a result of several factors: first, the pressure that carries through the capillary system from the arterial to the venous side; second, valves that prevent the regurgitation of blood after it has obtained a level or that prevent reflux flow from the deep to the superficial veins; third, the sucking effect of the negative intrathoracic pressure; and, fourth, the massaging action of the muscles through which the deep veins flow. The *superficial veins are supported only by skin and subcutaneous tissue* and are therefore much more likely to become dilated when subjected to prolonged or abnormal pressure.

The incompetent valve is the key to the disease of varicose veins. Valves may become incompetent as a result of long-standing increased venous pressure or when they are involved in a degenerative process such as thrombophlebitis. When the valves are incompetent, blood regurgitates from the deep veins into the superficial veins with resulting dilatation of this latter system. Incompetent valves in the main trunk of the greater saphenous allow blood to regurgitate into it from the femoral; blood regurgitates from the popliteal into the lesser saphenous when the valves are incompetent in that system. When the valves in the communicating vein become incompetent, blood flows in reverse from the deep to the superficial vein. Blood also may abnormally flow from one saphenous system into the other and result in dilatation of the veins of the other system.

Unfortunately, it has not been possible to correct the pathologic changes existing in the disease, and therefore treatment is based on either the obliteration of involved veins with a sclerosing solution or a surgical attack, which divides and ligates the superficial vein at its connection or connections with the deep system

and sometimes further strips the main trunk of the vein from the extremity. Surgical treatment is sometimes supplemented by injection therapy. The last half century has seen a complete swing of the pendulum in treatment. Removal of segments of veins was popular at the beginning of the century, but in time it gave way to the injection of sclerosing solutions. Because of recurrences after injection therapy, it was largely replaced in the 1930's by division and ligation of the greater saphenous at the foramen ovale and also of the lesser saphenous in the popliteal space when indicated. Sclerosing solution was either retrogradely injected into the system at that time or all palpable and visible veins were injected at a later time.

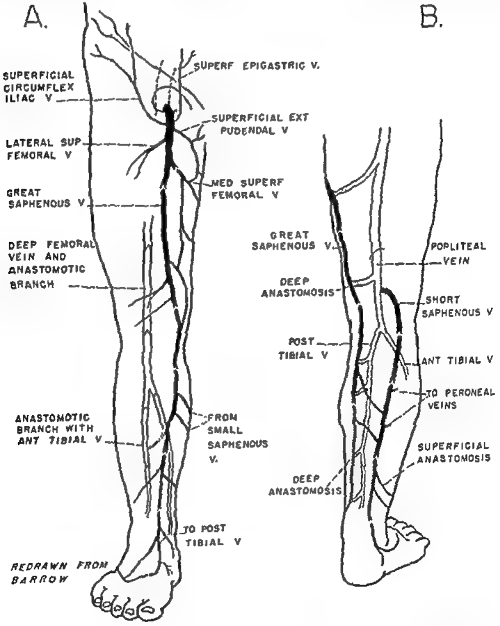

Fig. 63.—Diagram showing the great and short saphenous veins and their tributaries.

This method has proved satisfactory in some cases but in spite of careful selection of patients, there have been recurrences. Recurrences may result for the following reasons: failure to divide and ligate all branches of the greater saphenous at the foramen ovale; failure to recognize a connection between the greater saphenous and the femoral in the thigh at a level below the foramen ovale; failure to recognize

incompetent communicating veins between the two systems in the lower leg; and failure to recognize a dilated lesser saphenous vein with or without connections with the greater saphenous vein. Because of the unsatisfactory results with high division and ligation, therapy today also includes extirpation or stripping of the main trunk of the greater saphenous from the groin to the internal malleolus. In addition, every effort is made to recognize all incompetent communications so that these connections can be divided and ligated. The lesser saphenous is also divided and stripped when there is evidence of involvement of this system. Residual dilated veins are obliterated in some instances with a sclerosing solution although it must be borne in mind that there is danger of producing a deep venous thrombosis if the solution flows through a communicating vein into the deep system.

Each patient must be carefully studied and evaluated before any therapy is undertaken. The status of the deep venous circulation should be determined since superficial veins dilate sometimes as a result of their carrying a greater volume of the returning venous blood following deep vein thrombosis, in which case other surgical procedures may be indicated. Two tests are helpful in determining whether or not the deep veins are adequate. A tourniquet is applied above the knee tight enough to obliterate the greater saphenous and the patient is allowed to walk about. If no discomfort is experienced with the superficial group blocked and the varicose veins empty, the deep veins are probably patent. In the other test, the patient wears an Ace bandage several days and, again, if there is no discomfort with the superficial veins compressed, the deep veins are assumed to be adequate. The therapy of chronic thrombophlebitis of the deep veins is discussed later.

One must also be certain that the arterial circulation to the extremity is adequate. A lumbar sympathectomy may be indicated in some patients in order to improve the arterial circulation before proceeding with any vein surgery. This may be necessary in patients with chronic ulcers due to chronic thrombophlebitis of the deep veins, particularly when spasm is a factor.

Cellulitis of the leg and infected ulcers are cleaned up when present with hot wet dressings of boric acid or magnesium sulfate solution and antibiotic therapy before undertaking definitive surgery. Many ulcers heal promptly following the vein surgery, but occasionally healing may be so delayed because of the large size of an ulcer or the great amount of scar tissue about it that it is best to excise the ulcer and cover the defect with a split skin graft.

It is important to check the general cardiovascular status and to determine whether or not such systemic diseases as syphilis and diabetes mellitus are present. Some chronic ulcerations of the lower leg are malignant. This should be borne in mind and biopsies should be made of any suspicious lesions.

Every case should be carefully studied with tourniquets to locate the site of insufficiency even though one is planning to do a stripping operation. The Trendelenburg test or some modification of it is of value in locating the sites of incompetency. The modified Trendelenburg test, using multiple tourniquets, is probably of the greatest value (Fig. 64). With the leg elevated above the level of the heart in order to empty all superficial veins of blood, three tourniquets are applied snug enough to obliterate the superficial veins. The first tourniquet is applied just distal to the saphenofemoral junction in the upper thigh, the second

is applied above the knee, and the third just below the knee. The patient is then allowed to stand, and if it is found that previously identified varicose veins of the lower leg fill within less than thirty seconds, there are undoubtedly incompetent communicating veins between the deep and superficial systems in the lower leg.

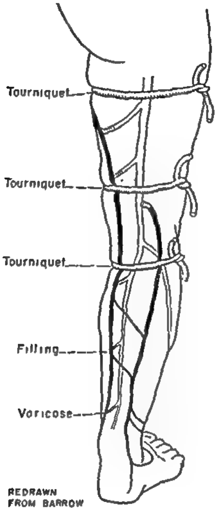

Fig. 64.—Method of carrying out modified Trendelenburg test with the three tourniquets in place.

The lowest tourniquet is then released. If previously empty veins fill following this, it indicates that there has been regurgitation of blood through the lesser saphenous vein. The middle tourniquet is next removed If previously empty veins fill following this, there are undoubtedly incompetent communicating deep veins between the deep and superficial systems in the thigh If veins fill following release of the upper tourniquet, it indicates that blood has regurgitated into the system through the saphenofemoral junction. The Mahorner-Ochsner test may also be of value in some cases A tourniquet is applied at various levels and the patient is allowed to walk about. If the veins empty with exercise, it indicates that there are no incompetent veins below the level of the tourniquet The level of the tourniquet may gradually be adjusted upward until the level of the incompetent vein is located If the incompetent point is at the saphenofemoral junction, the veins will empty with exercise when the tourniquet is applied at the highest possible point about the thigh.

Injection of Veins With Sclerosing Solution

Injection therapy as the only method of treatment is reserved for minor varicosities *when the Trendelenburg test is negative and the reason for obliterating the* vein is primarily a cosmetic one. It has already been stated that residual superficial varices should be obliterated after high division and ligation or stripping of the veins.

There are a number of good sclerosing solutions available. Sodium morrhuate, Monolate, Sylnasol, Sotradecol, and other solutions have all been used with success. A very small amount of solution should be injected the first time to determine whether or not the individual is sensitive to the solution. After this, 2 to 5 c.c. are injected at weekly intervals. A short beveled hypodermic needle is used. Great care must be used to prevent injection or leaking of the solution into the surrounding tissues, for otherwise a severe local reaction or actual sloughing of the tissues may result. The more peripheral veins are injected first. The needle is inserted into the selected vein with the patient standing. It is best then to milk the blood out of the vein with the thumb or to have the patient recline in order to empty the veins before injecting the solution since the maximum reaction will occur in an empty vein. An attempt is made to block a segment of veins to be injected above and below the point with the fingers in an effort to trap as much of the solution in this area as possible. Pressure is then applied over the site of injection with a small gauze pad for twenty-four hours. Elastic bandages or stockings should be worn throughout the period of injection therapy.

Division and *Ligation of the Greater Saphenous at the Foramen Ovale*

This may prove to be sufficient therapy if it is found that the veins do not fill promptly when the patient arises to a standing position with a tourniquet about the upper thigh previously applied with the leg elevated above the heart level. The addition of a low division and ligation of the greater saphenous in the lower thigh or about the knee to the high division and ligation is a useless procedure in our experience. Obviously it is a useless procedure if there are no channels from the deep system to the saphenous trunk between the site of the high and the low division. If there are connections between the two levels through which blood regurgitates, collateral channels will rapidly develop about the site of the low division and ligation. The actual communication must be divided and blood must not be allowed to regurgitate into the saphenous vein. Stripping of the greater saphenous trunk and the division and ligation of all incompetent communications are the best way to accomplish this. Division and ligation of the greater saphenous may be performed under local anesthesia in many instances. This allows the patient to become ambulatory immediately, which is very desirable. The procedure should be carried out in the operating room. Stripping of the vein requires a general anesthetic. Pentothal Sodium supplemented by ethylene or nitrous oxide is preferred, but spinal or gas-oxygen-ether mixtures may be used.

An incision beginning at a point where the femoral artery can be palpated as it emerges from beneath Poupart's ligament and extending downward and slightly mesial for 8 to 10 cm. is preferred to a straight vertical incision (Fig. 65). The incision is carried down through the superficial fascia and the main trunk of the greater saphenous vein is exposed. The femoral vessels lie beneath the deep

fascia in the femoral sheath and there should be no confusion as to their identity, although Luke and Miller have reported 21 disasters as a result of either the ligation, division, or retrograde injection of the femoral artery. Dissection of the branches of the saphenous is greatly facilitated at this point by dividing the main trunk between clamps. By holding up on the proximal end of the vein, one is able to identify the branches and divide and ligate them with ease. A small artery from the femoral runs across the saphenous vein near its junction with the femoral

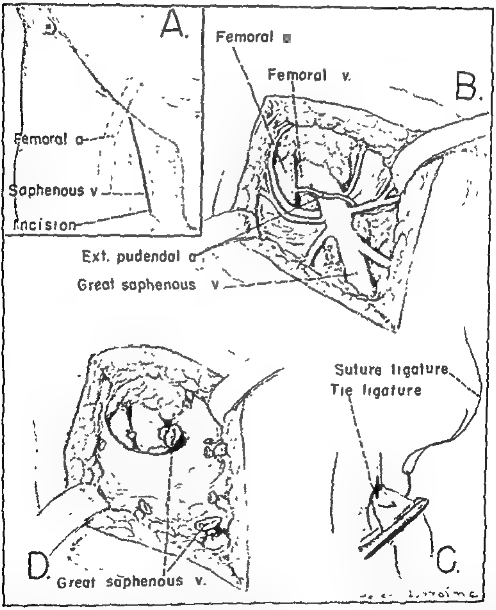

Fig. 65.—Division and ligation of saphenous vein *A*, Line of incision in relation to the vessels *B*, Dissection of the femoral vein and artery and their tributaries *C*, Method of ligating and transfixing the larger vessels *D*, The saphenous vein and its tributaries have been ligated and divided and small segments have been removed.

and division and ligation of this may be necessary for adequate exposure. The number of branches of the greater saphenous varies from two to five, and it is essential to divide and ligate all of them. The saphenofemoral junction is carefully identified before two hemostats are applied close to the junction, care being taken not to leave any of the saphenous as a blind channel in which a thrombus

could form and eventually propagate into the femoral. The upper end of the vein is first ligated with a free ligature of 30 cotton and the clamp closest to the femoral is removed. A suture ligature of the same material is next placed distally to the first ligature and the second clamp is removed. This ligature is placed distally to the free ligature in order not to have a ligature lying within the lumen of the vessel which might be the nidus of a thrombus. Approximately 10 cm. of the saphenous trunk is removed, and the distal end is doubly ligated in the same manner as the proximal end. Cotton or silk is preferred, but catgut of the appropriate size may be used. The incision is closed in layers with interrupted sutures in the fascia, subcutaneous tissue, and skin.

The retrograde injection of sclerosing solution into the distal vein is not advocated because of the severe reactions that sometimes follow this procedure, but residual veins may be injected later.

Stripping of Greater Saphenous Vein

If the greater saphenous is to be stripped, it is a good idea to extend the groin incision downward for another 5 cm. in order to expose a large branch from the mesial aspect of the thigh that joins the great saphenous in the upper third of the

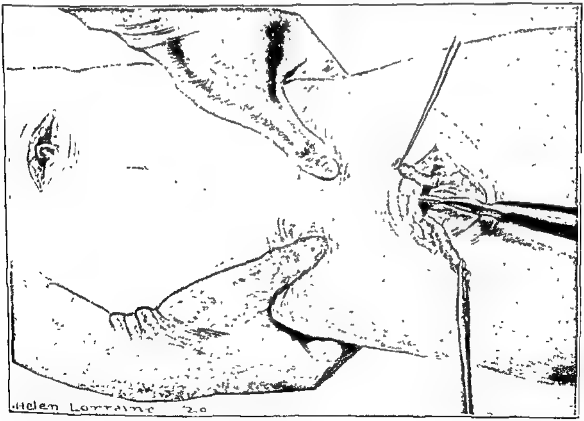

Fig 66—Mobilizing a varicose vein and stripping it from one incision to the other by method of C H Mayo.

thigh This branch is divided and ligated rather than stripped because it is difficult to apply pressure satisfactorily to control bleeding in the upper thigh A number of stripping technics have been described. One of these uses a periluminal instrument (Mayo) which breaks away the branches as it is passed downward around the vein (Fig. 66). Another technic uses an intraluminal instrument. Several instru-

ments of this type have been devised. The instrument is passed down the lumen of the vessel and all branches are stripped away, then it is withdrawn, inverting the vein on itself. The vein should be removed, if possible, from the groin to the region of the internal malleolus. Immediate pressure is applied to prevent bleeding from the ends of the torn branches. Some surgeons prefer to expose the greater saphenous at the internal malleolus and to pass the stripper upward from this point because the valves and the branches theoretically offer less obstruction to the

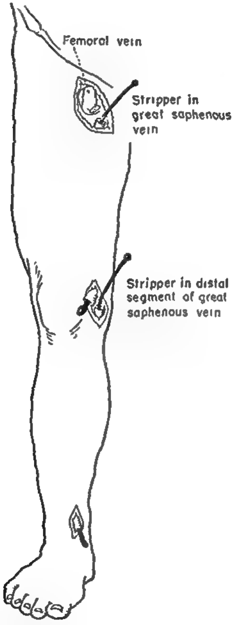

Fig 67.—Diagram showing use of Emerson stripper for varicose veins

passage of the stripper. A third technic employed by some surgeons uses no special instrument but depends on finger stripping. The main trunk is freed through the groin incision as low as possible, care being taken to divide and ligate all branches. A second incision is made at the level to which the vein has been stripped by the finger and in stepladder fashion the vein is dissected with the finger from one incision to the next until the entire trunk has been removed. This technic divides

and ligates all branches and so results in absolute hemostasis, but, on the other hand, it is tedious and time consuming.

The intraluminal stripping technic is generally employed today. One instrument (Emerson) is made of choke wire and has an olive tip at the end. The pliable wire allows the instrument to adopt itself to tortuous channels (Fig. 67). The intraluminal stripper, devised by Babcock, is made in sections with a semirigid shaft (Fig. 68). It may be possible to pass this instrument from the groin to the distal third of the lower leg, but an obstruction is often encountered first in the lower third of the thigh where a number of branches join the main trunk. An incision is made over this point and the branches are carefully divided and ligated.

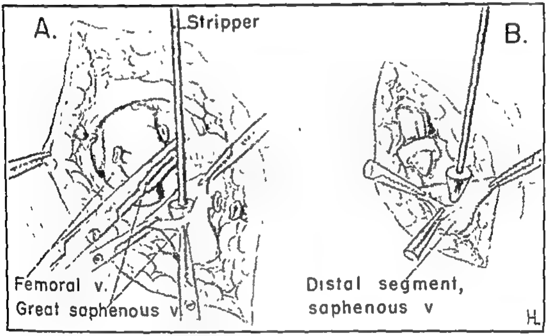

Fig. 68.—Insertion of Babcock's semirigid vein stripper: *A*, in the femoral region; *B*, in the distal segment of the saphenous vein

The main trunk is divided and a heavy ligature is tied about the upper end of the divided vein above the conelike tip of the stripper The stripper is not withdrawn upward until after another segment of the stripper has been passed downward from this point. An obstruction may again be encountered in the upper third of the lower leg where a number of branches join the trunk. The vein is again exposed and the branches are divided and ligated if this is the case. If the second segment of the stripper cannot be guided on beyond this point, the main trunk is again divided and a third segment is passed downward to the region of the ankle if possible. Since the conelike tip of the segments of the stripper are graded in size, it is possible to use a smaller size tip at the lower levels. After heavy ligatures have been tied about the vein above each tip, each section of the stripper is withdrawn, inverting the vein on itself and stripping it away from its bed. Pressure is immediately applied with a rolled towel over the course of the vein in the leg. By withdrawing all of the segments of the stripper at one time, an assistant is saved from having to apply pressure for a prolonged period of time. Occasionally the vein breaks in two, usually at the site where a branch joins the trunk. The vein is exposed through an incision at this level and another ligature is tied about the

vein after it has been picked up. All incisions are closed in layers with interrupted sutures. A pressure dressing using elastic bandages and mechanic's waste or folded abdominal pads over the course of the vein is then applied from the toes to the groin.

Patients are usually hospitalized for three or four days. They are encouraged to be up and about as soon as they recover from the anesthesia Pressure is maintained and the dressings are not disturbed except to readjust them until the seventh postoperative day when the sutures are removed. Ace bandages are worn for at least six or eight weeks after the operation. Chemotherapy is employed for forty to seventy-two hours after stripping in view of the extensive opening of tissue spaces and the possibility that extravasated blood may serve as a culture medium.

Division and Ligation of the Lesser Saphenous and Stripping of the Vein

Some surgeons have advocated stripping of the lesser saphenous vein in addition to the greater saphenous, but this should only be done when there is evidence of involvement. The lesser saphenous is exposed at its junction with the popliteal vein through a transverse incision in the popliteal space. All branches in the upper portion are divided and ligated with fine cotton. The main trunk is divided close to the popliteal junction. The proximal end is doubly ligated in the same manner as described for the great saphenous. The distal end is similarly ligated if the vein is not to be stripped. It may be difficult to insert a stripper, but if there is evidence of incompetent communicators, every effort should be made to remove the entire vein. Postoperative care is the same as that following operations on the great saphenous vein.

Division and Ligation of Incompetent Communicating Veins

Incompetent communicating veins are the most frequent reason for failure of therapy. In the care of the incompetent communicators in the thigh, stripping of the saphenous vein usually takes care of the condition unless there is a double saphenous trunk in the thigh and the one to which the communicator connects is not stripped. The second trunk connects with the first in the upper thigh and usually again connects to it in the upper third of the lower leg. One should be on the alert for this condition. This is another reason why it is preferable to expose the vein at various levels, particularly in the upper third of the lower leg, since the double saphenous trunk can often be recognized through this exposure. When there are multiple incompetent communicators between the two systems of the lower leg, all of them may not be taken care of by the stripping, and blood continues to regurgitate into segments of the saphenous system. It may be necessary to identify and then divide and ligate each of these connections separately These connections can be picked up on physical examination, but at times phlebograms have been found to be helpful in locating them In a few instances, it may be necessary to resort to the subfascial division and ligation of the communicators, as described by Linton. The involved veins may be in one of three groups: communicators to the posterior tibial mesially, the anterior tibial anteriorly, or the peroneal posterolaterally (Fig 69) A longitudinal incision is made down through the fascia the length of the lower leg in the area or areas involved All branches

are divided subfascially. The operation must be done under general anesthesia, and because of the extensive dissection it is probably advisable to expose only one group at a time.

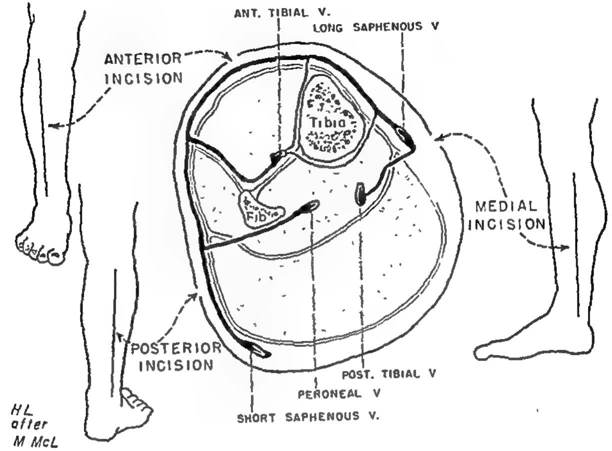

Fig 69.—Cross section through the mid portion of the lower leg and location of skin incisions, as recommended by Linton.

VENOUS THROMBOSIS

Thrombosis of veins may occur anywhere in the venous system, but this discussion is particularly concerned with the condition when it involves the veins of the lower extremity or the pelvis. Thrombosis most commonly involves the veins in the calf muscles of the legs. The condition may occur as a complication of operation, trauma, pregnancy, or any medical condition which confines the individual to bed for a long period of time.

In recent years two forms of the disease have been recognized—phlebothrombosis and thrombophlebitis. The former presents a minimal of inflammatory reaction, while the latter may show varying degrees of local and systemic inflammatory reaction. The conditions may only be different manifestations of the same process, but we do attempt to differentiate between the two. The clot in phlebothrombosis results from stasis and probable changes in the blood constituents which alter the clotting mechanism. The clot is not adherent to the vessel wall and easily breaks off in the blood stream, resulting in embolism. Thrombophlebitis is also caused by stasis, but other factors such as infection and trauma result in damage to the intima with the result that the clot is firmly adherent to the vessel wall. Embolism should, therefore, rarely occur in this latter condition.

Clinically, one is interested, first, in preventing the development of the condition and, second, in therapy to prevent, if possible, a clot from breaking off in the venous stream and producing a pulmonary embolism. General measures should be employed in all surgical cases in an attempt to prevent thrombosis. These prophylactic measures might be classified as conservative measures. All tissues should be handled as gently as possible in order to reduce tissue damage to a minimum. Preoperatively it is important to restore the blood volume to normal in order to maintain an adequate cardiac output, which is important in maintaining good blood flow. Postoperatively, deep breathing, leg exercises, and early ambulation are important in promoting good blood flow in order to prevent stasis. If the patient has varicose veins, Ace bandages should be worn during the immediate postoperative period. Blood volume must be maintained with adequate infusions of dextrose, electrolytes, and blood. Infection must be prevented or controlled. It has been suggested by Ochsner and his associates that lowered antithrombin levels in the blood may be a factor in intravascular clotting, and since circulating antithrombin may be alpha-tocopherol, they have given alpha-tocopherol acetate and calcium gluconate prophylactically.

In addition to the general prophylactic measures, certain specific measures have been advocated. Allen and his co-workers have employed prophylactically Dicumarol in all patients aged 40 to 65 years, undergoing major surgery. These patients are given 200 or 300 mg. of Dicumarol on the third postoperative day, and if there is no notable change in the prothrombin time, an additional 200 mg. is given on the fourth day postoperatively. Allen reports a reduction in the incidence of thrombophlebitis after the routine use of Dicumarol. Wise reports similar experiences. Allen also advocated the prophylactic division and ligation of both superficial femoral veins in patients 65 years of age and older before certain major surgical procedures in which there is a high incidence of pulmonary embolism. Operations for carcinoma, prostatism, and nailing of fractures of the hips fall in this category.

It has been our policy to individualize the treatment for each individual case. The routine use of Dicumarol prophylactically is not advocated because of the danger of hemorrhage. Although division and ligation of the superficial femoral vein is considered a safe procedure, sequelae are not entirely absent and surgical catastrophies—damage to the arterial supply—occasionally occur. Erb and Schumann have recently showed that prophylactic ligation of the superficial femoral vein is of questionable value.

All nonfatal cases of pulmonary embolism should have both superficial femoral veins divided and ligated. *If there is iliofemoral thrombosis, either the common* iliac should be divided and ligated or the inferior vena cava should be ligated in continuity. The latter procedure should be reserved as a lifesaving measure because of the high incidence of sequelae, as recently stressed by Shea. In septic thrombophlebitis involving the pelvic veins, such as is found after postabortal or postpartum sepsis, the vena cava probably should be ligated and both ovarian veins should be divided and ligated. The same procedure may be considered in cases of nonfatal pulmonary embolism when the pelvic veins following pelvic surgery are the possible site of venous thrombosis. If a diagnosis of phlebothrombosis is made,

both superficial femoral veins should be interrupted at once. Such a diagnosis may have to be based on minimal clinical findings.

Acute thrombophlebitis can be treated satisfactorily in most instances by conservative measures. The limb should be elevated on a pillow and compression bandages applied. Anticoagulant therapy is started at once after first obtaining a control prothrombin time. Prothrombin time should be maintained in the range between 35 and 40 per cent of normal. If heparin is used, the clotting time should be kept at approximately fifteen minutes. Therapy should be continued until the process has subsided, which usually takes from seven to ten days. In addition to the anticoagulant therapy, some form of vasodilatation should be employed. The injection of the lumbar sympathetic trunk on the involved side with procaine, as advocated by Ochsner, is the surest way of producing such a result. However, one of the general drug vasodilators may be used although they do not give selective vasodilatation as a sympathetic block. If fever continues in spite of conservative therapy, it may be advisable to do the ligation at the indicated level.

The deep veins of the lower extremity are most commonly the site of thrombosis, but the superficial saphenous system may be involved. If the saphenous veins are the site of an acute thrombophlebitis, division and ligation of the greater saphenous at the foramen ovale or of the lesser in the popliteal system is followed by rapid regression of the pathologic process.

Division and Ligation of the Femoral Vein

The patient is placed on the table with the head of the table elevated in order to increase venous pressure. This may aid in the extraction of the clot and prevent an embolus from breaking off and going to the lungs. The procedure is done usually under local anesthesia (Fig. 70). A 12 cm. longitudinal incision is made in the upper part of the anterior thigh over the femoral vessel or just mesial to the femoral pulsation, beginning at the point that Poupart's ligament crosses the vessels Superficial and deep fascia are incised and the femoral vein and its branches are exposed. The superficial femoral vein lies mesial and somewhat posterior to the artery and is exposed sometimes with difficulty. Care is taken to identify carefully the profunda branch of the femoral. A heavy ligature is then passed about the superficial femoral distally and about the common femoral as a means of controlling bleeding when the vein is opened. The superficial femoral vein is then opened between stay sutures. If a thrombus is found, it is carefully extracted. Aspiration with a glass tube or catheter introduced upward into the common femoral vein is a hazardous procedure but may be employed while the head of the table is elevated. If the clot is successfully removed, there should be free bleeding from each branch when the others are compressed. If there is free bleeding from all the branches, the superficial femoral vein is divided between clamps close up to where the profunda branch joins to make the common femoral vein. Each end is doubly ligated with two ligatures of 30 cotton. One of these ligatures is a transfixation ligature which is applied distally to the free ligature. If it is impossible to remove the thrombus from the common femoral, ligation should be done at a higher level. Homans has pointed out that ligation of the common femoral results in swelling of the leg because of inadequate collateral circulation about this point. Either the common iliac vein or the inferior vena cava should be ligated under this condition.

The incision is closed in layers with interrupted sutures of fine cotton. Catgut of the appropriate size may be used instead of the nonabsorbable sutures. Elastic bandages are applied to the extremity and early ambulation is employed. Even though there is no evidence of involvement of the opposite femoral system, the superficial femoral vein on the opposite side should also be divided and ligated.

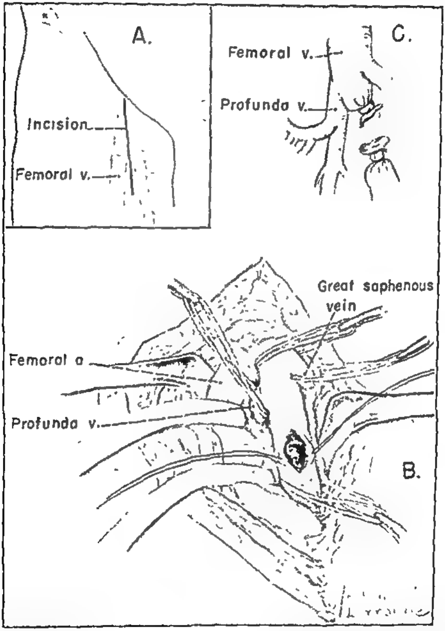

Fig. 70.—Division and ligation of superficial femoral vein *A*, Line of incision *B*, Incision made in the superficial femoral vein and the thrombus shown. *C*, The vein doubly ligated and divided.

Division and Ligation of Common Iliac Vein

The iliac vein is approached retroperitoneally, but if ligation of both vessels is indicated, it is simpler and better to ligate the vena cava The vessel is approached through a high McBurney type of muscle-splitting incision which is centered at the umbilicus The aponeurosis of the external oblique and the external muscle itself are divided in the direction of the fibers. The internal oblique muscle and the transversalis muscle are split and the peritoneum is exposed The dissection is car-

ried retroperitoneally and the peritoneum and its contents are retracted mesially with a large Deaver retractor. The vein is carefully isolated, and if it is technically possible, it is divided between clamps. The ends are then doubly ligated with two ligatures of 12 cotton. Because of technical difficulty, it is sometimes necessary simply to pass a ligature about the vessel with a ligature carrier and to ligate doubly the vessel in continuity. The incision is closed in layers with interrupted sutures of cotton or catgut.

Ligation of the Inferior Vena Cava and Ovarian Veins

This may be done retroperitoneally as in the division and ligation of the common iliac vein, but it can be done transperitoneally. This latter approach is advocated if the ovarian veins are to be divided and ligated at the same time. The retroperitoneal approach of the inferior vena cava is from the right side (Fig. 71).

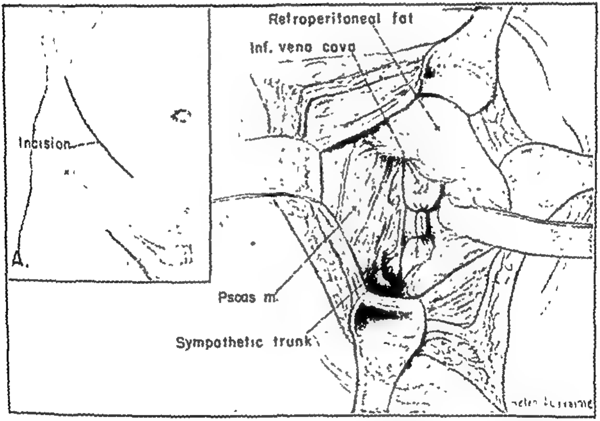

Fig. 71.—Retroperitoneal ligation of the inferior vena cava. The vessel is doubly ligated in continuity. Inset *A* shows position of the incision.

The vessel is ligated in continuity. It is carefully isolated and a heavy ligature, either of braided silk or a double ligature of 12 cotton, is passed around the vessel with a ligature carrier. The ligature is tied securely and a second ligature is placed about the vessel approximately 1 cm. away from the first ligature. The incision is closed in layers with interrupted sutures of cotton or catgut. Ace bandages are applied to the extremities, and early ambulation is practiced. Some form of elastic support should be worn for a minimum of three months, and longer if there is any swelling of the extremity.

The inferior vena cava may be exposed transperitoneally through a right paramedian incision. The peritoneum is divided lateral to the cecum and ascending

colon and the vena cava is exposed retroperitoneally. It is doubly ligated *in continuity* as previously described. The right ovarian vein is also identified and is divided and ligated at the level of the pelvic brim. If a clot is present in the vein, the ligation should take place above this point. Double ligatures of cotton are applied about the ends of the ovarian vein. The posterior peritoneum is resutured with a continuous suture of plain catgut. The posterior peritoneum on the left side is then divided lateral to the sigmoid colon, and the left ovarian vein is exposed retroperitoneally. It is divided and ligated as was done on the right with double ligatures of cotton. The posterior peritoneum is reapproximated with a continuous suture of plain catgut. The abdominal incision is closed in layers, as has been described elsewhere.

Chronic Thrombophlebitis

Chronic thrombophlebitis of the veins of the lower extremity is usually a great deal more disabling than varicose veins. In addition to chronic swelling of the part, there may be severe aching of the limb, stasis pigmentation and eczema, and ulceration. Linton has pointed out that these changes are secondary to increased venous pressure in the lower extremity as a result of damage to the venous system and their valves by the disease. It was stated earlier that lumbar sympathectomy might be indicated in those cases of chronic thrombophlebitic ulceration with vasospasm As Linton has pointed out, lumbar sympathectomy is not necessary to cure a simple varicose ulcer. It may be necessary as an adjunct to therapy in chronic thrombophlebitic ulcers, particularly in those cases with marked hyperhidrosis. Linton has advocated interruption of the superficial femoral vein and ablation of the superficial veins by stripping of the greater and lesser saphenous veins.

The rationale of dividing the superficial femoral vein as pointed out by Linton is to decrease the head of pressure which is exerted on the veins of the lower leg by the long column of unsupported blood. Normally, the valves support the column in segments and thus decrease the venous pressure exerted on the skin and subcutaneous tissue. Although the vein recanalizes after the acute condition, the valves are destroyed and a semirigid, toneless tube is left which acts more as a reservoir than a channel for the passage of blood.

The results with the Linton operation have not always been satisfactory. There is a general feeling of caution today in approaching the problem of chronic thrombophlebitis, particularly when complicated with ulcers. Many of the patients are going to have to learn to live with their legs It is probably wise to apply the therapeutic measures step by step. If therapeutic lumbar sympathetic blocks with procaine decrease the size of the leg, lumbar sympathectomy is indicated as the first step In case the results are unsatisfactory, the superficial veins are first stripped and the results are observed before a decision is made to employ deep vein interruption.

Interruption of Superficial Femoral Vein and Ablation of Superficial Veins—Linton Operation

A vertical incision is made in the upper thigh over the course of the femoral vessels, beginning at the point where Poupart's ligament crosses the vessels and extending downward for 15 cm. The saphenous vein is first divided and ligated at

the saphenofemoral junction along with all its branches, according to the technic previously described. The femoral sheath is then opened and the superficial femoral vein is carefully exposed. It lies mesially and somewhat posterior to the artery at this point. Because of previous reaction about it, it is usually thickened and adherent to the artery. After the profunda branch has been carefully identified, the superficial femoral vein is divided and ligated just distal to it. The division is made close to the profunda so as not to leave a blind pocket in which a thrombus might form. The ends of the vein are doubly ligated with two ligatures of 30 cotton. An intraluminal stripper is then inserted in the great saphenous and the vein is stripped from the ankle to the groin. Stripping is often difficult because of the scar tissue reaction about the vein in the lower leg. The patient is turned and the lesser saphenous vein is exposed in the popliteal space through a transverse incision. It is divided and the proximal end is ligated as previously described. The stripper is inserted and the trunk is stripped from the region of the external malleolus up. All incisions are closed with interrupted sutures of cotton. A resilient pressure dressing is applied from the toes to the groin. Penicillin therapy is given both pre- and postoperatively. The patient is ambulated early, but remains in the hospital until the sutures are removed on the seventh postoperative day. Elastic bandages should be worn for at least six months or longer after this operation In some cases it is advisable for the patient to wear an elastic support indefinitely.

OBSTRUCTION OF LYMPHATICS OF EXTREMITIES

Chronic lymphedema of the extremities due to obstruction of the lymphatic channels in certain instances may be amenable to surgical therapy, although the results have not been too encouraging through the years. The types amenable to surgery fall into two groups: idiopathic and acquired. Familial (Milroy's) lymphedema is the common example of the idiopathic group, while the acquired lymphedema is usually the result of accidental or surgical trauma which is often complicated by infection and, in the tropics, is a result of blockage of the lymphatics by *Filaria bancrofti.*

In the upper extremity chronic lymphedema most commonly occurs following radical mastectomy for carcinoma of the breast. Although the main lymphatic trunks are removed in the operation, collaterals usually develop and lymphedema is either transient or minimal in amount. If infection should intervene, adequate collaterals may not develop and chronic lymphedema remains permanent. In the lower extremity the most commonly seen type is Milroy's—familial lymphedema. Infection may be the factor in some cases. The incidence of lymphedema has possibly been reduced in recent years as a result of control of infection by antibiotics

Handley's Operation

None of the operations devised for the relief of lymphatic obstruction in the extremities has been entirely satisfactory. Handley first attempted to treat lymphatic obstruction of the extremities by introducing long silk threads in the subcutaneous tissue of the extremity, then across the area of obstruction (axilla or groin) to the subcutaneous tissue of the trunk He hoped in this way to stimulate the development of collateral channels (Figs. 72 and 73). The results were not permanent and the operation is now chiefly of historic interest. In the light of our present

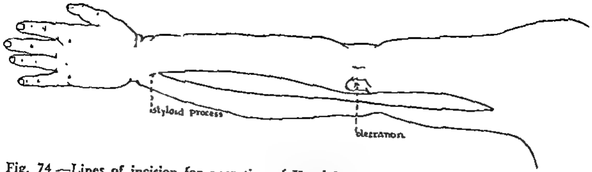

Fig. 74.—Lines of incision for operation of Kondoleon along the posterolateral surface of the upper extremity.

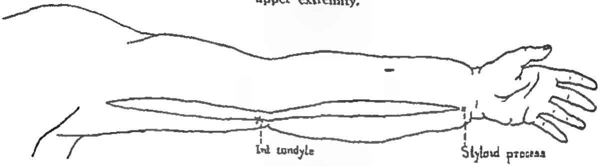

Fig. 75.—Lines of incision for operation of Kondoleon along the anteromedial surface of the upper extremity.

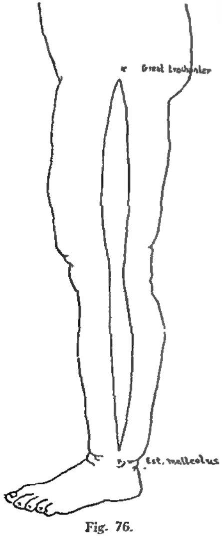

Fig. 76.

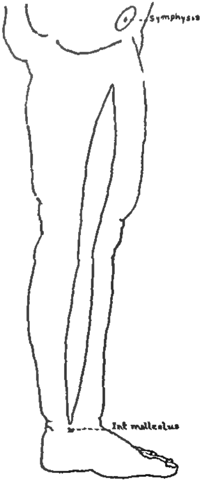

Fig. 77.

Fig. 76.—Lines of incision for operation of Kondoleon on lateral surface of the lower extremity.

Fig. 77.—Lines of incision for operation of Kondoleon on medial surface of the lower extremity.

In the operation devised by Poth and his associates, split skin grafts are removed from the entire circumference of the extremity except for a narrow strip over the anterior surface of the tibia. The remaining tissues down to the muscles except for the narrow strip over the tibia are excised. The muscles are then covered with the split skin grafts previously removed. At a second stage the subcutaneous tissue and fascia are removed from beneath the narrow strip over the anterior surface of the tibia.

Postoperatively, the legs are elevated for at least three weeks and elastic bandages are worn for months and sometimes even indefinitely. These operations are extensive and justified only in the moderately advanced or advanced cases.

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CHAPTER 12

DUPUYTREN'S CONTRACTURE; INFECTIONS OF THE HAND AND FOREARM

Benjamin W. Rawles, Jr.

DUPUYTREN'S CONTRACTURE OF THE HAND

Since Dupuytren's contracture involves the palmar fascia primarily and the adjacent skin secondarily, operations should be directed toward the division or preferably the excision of the contracted portion of these structures. Most surgeons now adopt open excision of the thickened palmar fascia with a considerable margin of normal fascia and the hopelessly involved skin with primary closure of the wound as the treatment of choice. A. A. Davis, one of the few recent writers to take exception to this view, advocates multiple subcutaneous division of the fascia, especially in laborers. He suggests that it will frequently be necessary to repeat the procedure but believes this is justifiable because of the poor results obtained by the more radical operations In the group of thirty-one cases he studied, only 38 per cent of those subjected to open excision of the palmar fascia obtained a perfect result, while 75 per cent of those treated by multiple subcutaneous division of the fascia obtained a satisfactory result.

These results are not in agreement with those published by Kanavel, Koch, and Mason, J. S. Davis and Finesilver, and others. Kanavel and his associates reported good results in 69 per cent of their cases subjected to the more radical procedures. While J. S Davis and Finesilver do not give definite figures as to their results, they strongly advise the open operation and urge as complete excision of the palmar fascia as possible. They do suggest, however, that multiple subcutaneous division of the fascia should be used in cases where the more extensive procedures are inadvisable. Both Koch and J. S. Davis advise excision of all grossly involved skin and the use of whole thickness skin grafts when necessary for primary closure.

Excision of Palmar Fascia

This procedure is carried out under general anesthesia A tourniquet is used since a bloodless field is so essential to the meticulous dissection. All of the affected palmar fascia and the extensions into the deep palm and into the fingers must be removed. Incisions, as far as possible, are placed in flexion creases One incision is made along the distal flexion crease in the palm and one along the flexion crease of the thumb. The skin is carefully dissected away from the underlying fascia until the fascia is completely exposed. The dissection is begun at the base of the palm and is carried distally, care being taken not to injure the distal vessels or nerves

The septa running deep in the palm are divided as deeply as possible, and the affected fascia extending into the fingers is all carefully dissected out. This may require an incision along the lateral aspect of the proximal pad with an L-shaped extension across the proximal interphalangeal flexion crease. Absolute hemostasis is essential after removal of the tourniquet. Some of the skin may be so calloused that it has to be removed, or parts of it may become nonviable as the result of dissection from the underlying tissues so that it has to be cut away. These defects are covered with full thickness skin grafts. The skin edges are carefully approximated with cotton or silk sutures and a resilient pressure dressing is applied with the hand in extension. Physiotherapy is begun as soon as healing will permit.

Multiple Subcutaneous Fascial Division

Multiple subcutaneous division of the palmar fascia is performed by inserting a small-bladed, sharp tenotomy knife beneath the skin at the ulnar border of the hand and passing it between the skin and the thickened fascia; then, while the involved fingers are extended, the knife blade is turned toward the fascia and that tense fibrous structure is divided. The operation has the same objections as all other blind procedures; namely, the danger of injuring adjacent structures, especially vessels, nerves, and tendons. It is also considered to be inadequate for most cases.

INFECTIONS OF THE HAND AND FOREARM

Because of the close anatomic relationship between the hand and forearm, infections of these areas should be considered together. The palmar synovial sheaths of the flexor tendons (radial and ulnar bursae) extend from the hand into the forearm, deep to the transverse carpal ligament. When distended with pus these bursae are apt to rupture at their proximal ends into the major fascial space of the forearm. Lymphatic infections of the forearm also are usually secondary to infections of the hand.

So far as treatment is concerned, there are two chief types of infection of the hand and forearm: that which gives rise to lymphangitis and cellulitis and is to be treated conservatively, and that which tends to localize and form pus and therefore requires surgical intervention. These types may be further divided into those infections which, because of the anatomic structures involved, are characteristic of the location, as infection of the flexor tendon sheaths; and those similar to infections in other parts of the body, as furuncles and carbuncles. The latter are treated in much the same manner as elsewhere in the body and therefore call for no detailed discussion other than to emphasize the necessity for care in incising such infected areas, especially on the fingers, because of the proximity of important underlying structures.

Since the anatomy of the hand and forearm is complex, it is necessary to have a detailed knowledge of it before one can hope to understand the manner of development, routes of extension, and methods of treatment of infections in this area. Surgeons who are called upon to treat such infections should familiarize themselves with the anatomy and pathology of this region by reading the excellent monographs on this subject by Kanavel, Auchincloss, Hart Bunnell, and Brickel. Satisfactory treatment of infections of the hand and forearm requires, first, recognition of the spaces involved and, second, the institution of adequate drainage through a properly placed incision.

A few minor infections of the fingers may be operated upon either without an anesthetic or with regional anesthesia, but as a rule it is better to use general anesthesia for drainage of infections of the hand and forearm. A tourniquet may be very helpful in providing a bloodless field for incision and drainage and is mandatory for drainage of tendon sheaths.

Eponychia and Paronychia

Eponychia and paronychia usually result from trivial injuries along the nail border and, if properly treated in the beginning, are readily cured. A considerable number develop from infected hangnails and improper methods of manicure. If hangnails are treated by the application of a mild antiseptic at the onset of the inflammation, the vast majority of them will clear up promptly. If they are somewhat more advanced, they can usually be cured by applying wet dressings of about 50 per cent alcohol for a few hours; but if the infection has developed to the point of forming a small purulent blister lateral to the nail, the roof of the blister should be excised and a hot wet dressing applied. If the infection has extended beneath the border of the nail, adequate drainage may be obtained by pushing the cuticle back; but if it involves the root of the nail, that portion of the nail which has become separated from the matrix should be excised. In more advanced cases of subungual infection, it may be necessary to make an incision at the lateral border of the nail, extending to the posterior portion of the sulcus. An incision should never be made over the root matrix as this may result in injury to it which will be followed by a cleft nail After the lateral incision is made, the eponychium is pushed back to expose the base of the nail and the depths of the sulcus, all of the detached nail is excised, and a small piece of petrolatum gauze is inserted beneath the soft tissue flap. In very advanced cases it may be necessary to make bilateral incisions to elevate the entire eponychium. *It should be emphasized, however, that it is rarely necessary to make an incision if the infection is treated properly in the early stages.* If it is neglected and allowed to go on to a chronic subungual abscess, the distal phalanx may become involved and this may eventually necessitate its removal.

Anterior Closed Space Infections or Felons

Infection in the anterior closed space of the distal phalanx is often the result of pricking the finger with a needle or pin. The infection thus introduced within the dense fibrous wall of this space develops in the looser tissues and causes a marked degree of tension. The arteries supplying the diaphysis pass through the anterior closed space on their way to the bone, and, therefore, when increased tension develops, the blood supply to the bone may be cut off and a sequestrum formed. It is essential, therefore, that infections in this region be drained before the blood supply to the bone is impaired. The diagnosis of felon in the early stages is not difficult because of the severe throbbing pain associated with induration and tenderness of the palmar surface of the distal phalanx

Not infrequently these infections are treated by a longitudinal midline incision, but this is undesirable. Since the fibrous trabeculae are perpendicular to the surface, it does not give adequate drainage. It also leaves a scar which interferes seriously with the sensation of the palmar surface of the distal phalanx. In early infections an incision should be made, extending from a short distance distal to the

distal flexion crease of the finger along the anterolateral border of the finger to near the tip, the so-called "hockey stick" incision (Fig. 78). In this way the trabeculae are divided and drainage is improved. The side on which this incision is to be made can usually be determined by careful palpation of the distal phalanx. If

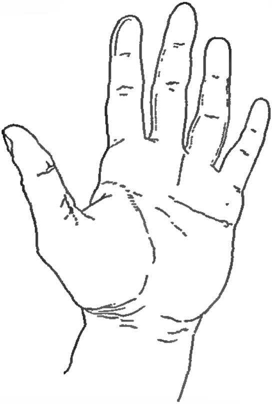

Fig. 78.—Hockey stick incision for drainage of anterior closed space infection, lateral incisions for drainage of flexor tendon sheaths, and incisions for drainage of proximal portion of flexor tendon sheaths and lumbrical spaces. (Kanavel.)

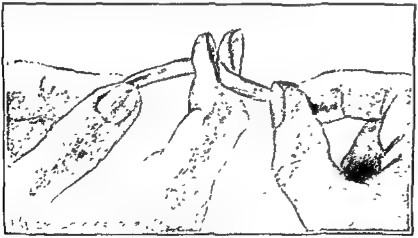

Fig 79—Method of Dorrance for incision of felon. This incision should be reserved for the more advanced cases.

the process is advanced, it is probably best to follow Dorrance's suggestion to make a horseshoe-shaped incision extending from a short distance distal to the distal flexion crease on one side around the tip of the finger to the same position on the opposite side. The fibrous trabeculae are divided near the palmar surface of the bone and a small piece of silk or rubber tissue is inserted to prevent too rapid heal-

ing (Fig. 79). This incision gives excellent drainage but leaves a rather extensive scar, and its use should therefore be reserved for more advanced cases. It is important not to begin the incision too near the flexion crease so that injury to the terminal portion of the tendon sheath will be avoided; and the incision should not be placed too far toward the dorsal surface of the finger, as the blood vessels supplying the phalanx may be injured.

Collar Button Abscesses of the Palm

Individuals with thick calluses in the palm of the hand are liable to develop infection beneath these areas which may result in the so-called collar button type of abscess. Infection beneath the callus forms a relatively superficial abscess, but the dense overlying tissue may cause the pus to burrow into the deeper tissues through the thin distal portion of the palmar fascia. It is extremely important, therefore, to excise the roof of the superficial abscess and inspect its floor carefully to determine whether there is a small sinus connecting with a deeper abscess. If there are suspicious areas in the floor of the abscess, they should be examined with a small probe, and if a collar button type of abscess is found, it should be given adequate drainage, if necessary, by dividing completely the web space. This, fortunately, heals readily and does not give any appreciable disability.

Infections of the Tendon Sheaths

Infections of the dorsal tendon sheaths are relatively infrequent and less serious than when the flexor tendon sheaths are infected. Extensor tendon sheath infections are best treated by a simple longitudinal incision. This gives adequate drainage and is usually followed by a rapid clearing up of the infection.

It is absolutely essential that surgeons treating infections of the hand have a clear understanding of the anatomy of the flexor tendon sheaths (Fig. 80). Those of the index, middle, and ring fingers extend from approximately the level of the distal flexion crease of the finger to a point about 2.5 cm. proximal to the base of the finger. In most cases there is no connection between these sheaths and either the radial or ulnar bursa, but the tendon sheath of the ring finger may communicate with the ulnar bursa. When the sheaths become distended with pus, they are apt to rupture into the deep fascial spaces of the hand. Infection in the sheath of the index finger ruptures into the thenar space, and infection in the sheath of the ring finger into the middle palmar space. While infection in the middle finger sheath may open into either of these spaces, it usually ruptures into the middle palmar space. The sheath of the flexor pollicis longus tendon is continuous with the radial bursa which extends deep to the transverse carpal ligament, and the sheath of the flexor tendons of the little finger is usually continuous with the ulnar bursa which also extends deep to the transverse carpal ligament into the forearm. There is not infrequently a communication between these bursae so that infection in one will spread to the other and also to the major fascial space of the forearm unless early adequate treatment is given. The major fascial space lies between the flexor digitorum profundus tendons and the pronator quadratus muscle distally, and the flexor digitorum profundus tendons and the interosseous membrane proximally. It is obvious, therefore, that infection in either the radial or ulnar bursa is likely to lead to

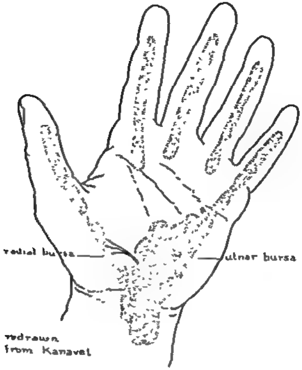

Fig. 80.—Outline of flexor tendon sheaths and radial and ulnar bursae. (Kanavel.)

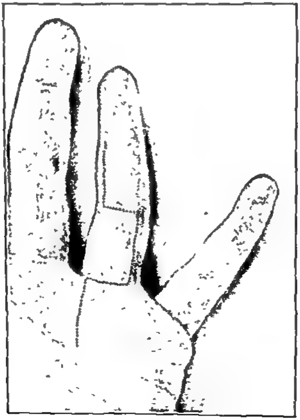

Fig. 81.—Line of incision which may be used for drainage of severe infection of the flexor tendon sheaths of the index, middle, or ring fingers.

infection in the other bursa and also in the major fascial spaces of the forearm unless adequate drainage is given early.

Several incisions have been devised for drainage of the *flexor tendon sheaths of the three middle fingers.* These sheaths are sometimes opened by a single long midline incision, but this should not be done as it leads to a dense scar on the palmar surface which gradually contracts and interferes with the extension of the finger as well as with palmar sensation. Kanavel advocated either single or double anterolateral incisions, the unilateral incision in early cases and the double incision only in more advanced cases (Fig 78). He also advised that the tendon sheath be opened laterally. Auchincloss advises lateral incisions with small cross incisions at the level of the flexion creases, and opens the tendon sheath in the midline.

The following incision has been used with considerable satisfaction for infection of the tendon sheaths of the three middle fingers (Fig. 81). It begins at the distal flexion crease of the finger at a point on one side anterior to the digital vessels to avoid injury to the blood supply to the finger; it is carried proximally to the middle flexion crease of the finger, along the middle flexion crease to a corresponding point on the opposite side, then to the proximal flexion crease, along the proximal flexion crease to that side of the finger on which the incision began; and finally it is carried up on the palm for a distance of about 2.5 cm The incision is carried through the skin and subcutaneous tissue and the flaps are dissected over nearly to the midline, thus exposing the tendon sheath, which, if grossly involved, is incised in or near the midline. In less advanced infections two lateral incisions are made in the sheath, leaving a small bridge at the site of the middle flexion crease to prevent prolapse of the tendon. This incision gives excellent drainage and the blood supply to the flaps is good. If the skin flaps become displaced later they may have to be freed and sutured in position to prevent a disfiguring scar. Because of this possibility, it is probably best to reserve this incision for late cases.

If there is evidence of infection in the lumbrical spaces, they should be opened through that portion of the incision used to drain the palmar portion of the tendon sheath. If there is greater tenderness over one lumbrical space, the incision should be made so that the palmar extension lies over that side.

It is better not to use any form of drainage material, but if it is felt that this is essential, a thin strip of silk or rubber tissue may be used. If drainage material is not used, it will probably be necessary to keep the incision open by gently separating the wound edges with a hemostat at each dressing

It is extremely important to use a careful aseptic technic during the operation and at subsequent dressings, as these infections are usually due to streptococci, and if staphylococci are introduced there is a much greater tendency for pockets to form and thereby prolong the infection. Active motion should be started as soon as possible after drainage has been established, and both active and passive motion should be carried out until there is a complete return of function (Figs. 82 and 83), or until no further improvement is apparent.

Infection of the flexor tendon sheath of the little finger is drained through the same type of incision on the finger as is used in the other flexor tendon sheaths, and, if the ulnar bursa is involved, the incision is carried proximally along the radial side of the hypothenar eminence to a point near the transverse carpal ligament If the entire ulnar bursa is involved, an additional incision should begin about 3 cm

proximal to the styloid process of the ulna over the lateral portion of its volar surface, extending proximally for 7 cm. This incision is carried through the skin and subcutaneous tissue, the muscular attachments to the ulna are divided, and the tissues are dissected away from the volar surface of the ulnar as far toward the midline of the forearm as the ulnar bursa. This procedure will usually suffice, but if the bursa has not ruptured into the fascial space of the forearm, it should be opened by a hemostat. In advanced infection or if there is very marked swelling, it may be wise to extend the palmar incision through the transverse carpal ligament, completely dividing it. This gives better drainage and releases the pressure on the structures behind the ligament. The latter procedure, however, should be

Fig 82.

Fig. 83.

Figs. 82 and 83.—Photographs showing an almost complete return of function six weeks after drainage of an early suppurative tenosynovitis of the flexor tendon sheath of the ring finger.

reserved for unusual cases. If the bursa has already ruptured into the forearm and if the infection has obviously extended upward, Kanavel advised a second incision in the forearm about midway between the wrist and elbow, a short distance in front of the ulna, to expose the junction between the flexor carpi ulnaris and the flexor digitorum sublimis muscles. These muscles are separated with care not to injure the ulnar artery, and drainage is instituted

When the middle palmar space is involved secondary to infection of the flexor sheath of the little finger without extension to the ulnar bursa, an incision is made

over the adjacent lumbrical space, a hemostat is passed posterior to the tendon sheaths, and the middle palmar space is drained. If the ulnar bursa is also involved, the hemostat may be passed through the wall of the bursa and into the infected midpalmar space.

To avoid spread to the ulnar bursa or to the major fascial space of the forearm, infection in the sheath of the flexor pollicis longus tendon should be given adequate drainage as soon as the diagnosis is made. The incision begins anterolaterally at the distal flexion crease of the thumb and is carried proximally along the ulnar side of the thenar eminence to within 3 cm. of the transverse carpal ligament. Kanavel showed that it is unwise to extend the incision nearer the transverse carpal ligament than this, as there is danger of injuring the motor branch of the median nerve to the thenar muscles.

If the entire flexor pollicis longus sheath and radial bursa are obviously involved, drainage should be instituted proximal to the transverse carpal ligament. This may be done either through an incision on the radial side or through the incision used for draining the infection of the proximal portion of the ulnar bursa Infections in either bursa are apt to lead to rupture into the fascial space in the forearm. If the bursa has not ruptured, it may be opened by a hemostat, as suggested in infections of the ulnar bursa.

Infections in the Deep Fascial Spaces of the Hand

Infection in the dorsal subaponeurotic space of the hand is best treated by longitudinal incision between the extensor tendons which overlie the dorsal surface of the metacarpal bones. Only one longitudinal incision is usually necessary to drain this space adequately, but this incision should extend throughout practically the entire length of the space.

The two most important fascial spaces in the palm of the hand are the thenar and the middle palmar spaces (Fig. 84). As already stated, infection in these spaces may result from infection in the flexor tendon sheaths, especially those of the three middle fingers. Infection in the thenar space is best treated by an incision along the palmar border of the radial side of the metacarpal bone of the index finger (Fig 85). The incision is carried through the skin, subcutaneous tissue, and fascia. A hemostat is inserted and directed immediately anterior to the palmar surface of the metacarpal bone and slightly proximally into the thenar space, then opened and withdrawn, releasing the pus. If necessary, a small strip of rubber tissue is inserted for drainage. The middle palmar space is drained through a transverse incision placed in the distal flexion crease of the hand (Fig. 86). The infection lies beneath the flexor tendons to the middle and ring fingers. A hemostat is carefully inserted into the space between the tendons and drainage is established. It is usually best to insert a small rubber tissue drain In opening either of these spaces, it is important not to carry the instrument beyond the midline of the metacarpal bone of the middle finger, as the septum between the thenar and midpalmar spaces may be penetrated

Human Bite Infections of the Hand

Among the most serious infections of the hand are those due to human bite. Under this general term are grouped all lacerations of the tissues by human teeth regardless of the manner in which the injury is received Such injuries naturally

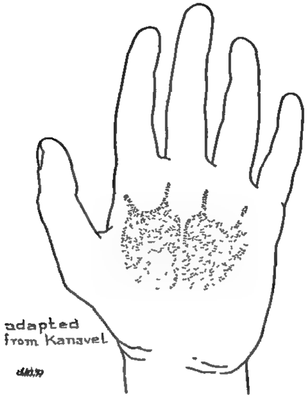

Fig. 84.—Outline of the middle palmar and thenar spaces. (Kanavel.)

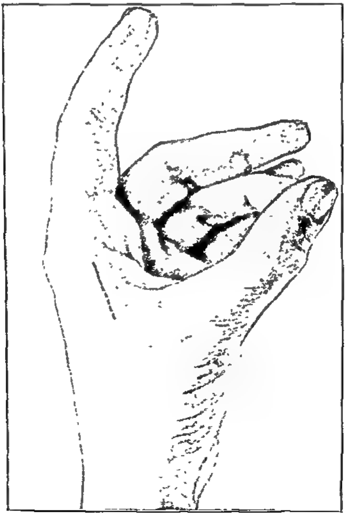

Fig. 85.—Line of incision for drainage of thenar space. (Kanavel.) (Redrawn by Helen Lorraine.)

occur to any part of the body, but the hand is affected more *frequently* other areas. The part most frequently involved is the dorsal aspect of the r carpophalangeal joints of the right hand. Injury to this area usually results a blow with the closed fist against the upper incisor teeth. This combinatic circumstances partially explains the seriousness of the injury, for the double produces tension over the knuckles including the extensor tendons, and the ti are therefore easily divided. Not infrequently both the extensor tendon and capsule of the joint are penetrated, and the tendon is usually contaminated when it is not divided. When the fingers are extended, the tendon moves pı mally and thus contaminates the tissues proximal to the opening. This ha important bearing on the immediate treatment of such a case.

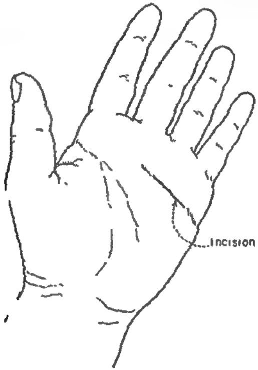

Fig. 86—Line of incision for drainage of middle palmar space

The organisms in the mouth are usually highly virulent aerobes and anaerol and when deposited in such areas as the joints or cellular tissue, away from t wound of entrance, may give rise to extremely serious infections. Infection u usually occurs in the subaponeurotic space of the dorsum of the hand and in t subfascial space of the proximal phalanax Infection may spread to one or mc of the important structures and spaces of the hand, the route depending upon t tissues involved in the original injury. It may spread distally beneath the digit fascia and eventually involve the phalanx, or it may extend around the finger enter the lumbrical canals. Proximal extension along the lumbrical canals w involve the deep fascial spaces of the palm. It is important for the surgeon wl treats such cases to bear *in mind these routes for spread of* the *infection*, so th involvement of any particular structure or space will be noted early.

Immediate treatment of human bites is most important. The superficial pa of the wound should be enlarged and a careful examination made to determir which structures are wounded. If the tendon is injured, an incision should be mad

which will expose it and the adjacent tissues for a short distance, 1 to 1.5 cm., proximal to the wound. All badly injured tissue should be excised and the wound should be thoroughly irrigated with warm normal saline solution. Sutures should not be used, even in the tendons. The hand and forearm are put at rest on a palmar splint and the patient is confined to bed, preferably in a hospital where the hand can be watched closely. The subsequent treatment will naturally depend upon whether the wound becomes infected and upon the routes by which the infection spreads.

Postoperative Principles in Hand and Forearm Infections

The hand and wrist are placed in a splint in the position of optimum function and a large sterile dressing is applied. The dressing is kept soaked with warm boric acid or magnesium sulfate solution and heat is maintained with hot-water bottles. Antibiotic therapy is instituted. The dressing is changed in twenty-four hours under strict aseptic technic to determine whether or not adequate drainage has been provided and whether or not there has been spread of infection to other spaces. The drains are removed in forty-eight to seventy-two hours and the wet dressings are discontinued as soon as possible to prevent unnecessary maceration of skin. Physiotherapy is begun as soon as healing will permit.

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CHAPTER 13

WOUNDS OF SOFT TISSUES; CARBUNCLES; PILONIDAL CYSTS AND SINUSES; TUMORS, BENIGN AND MALIGNANT; MELANOMA

HARRY J. WARTHEN, JR.

WOUNDS OF SOFT TISSUES

Wounds of the soft parts incurred under peacetime conditions frequently are not treated with the care which they deserve. The introduction of antibiotics and sulfonamides has not been an unmixed blessing, for some surgeons have relied upon the general effects of these agents to compensate for shortcomings in the local treatment of the condition

The extent of the injury and the causative agent determine in large measure the type of treatment. Wounds made by sharp objects, in general, respond to simple cleansing and closure, whereas injuries caused by blunt force require careful excision of devitalized tissue, in addition to the measures mentioned above.

The type of anesthetic used will depend upon the age and general condition of the patient as well as the extent of the injury and the likelihood of infection.

In a clean-cut and limited wound of recent origin, a local anesthetic carries minimal danger of spreading infection and avoids the hazard and associated inconveniences of a general anesthetic While the anesthetic may be injected at a distance, a more painless method and one of especial value in the treatment of injuries in childhood is to insert the solution beneath the margins of the laceration into the subcutaneous tissues about the circumference of the wound This method is of less value in the more massive injuries and should not be attempted where extensive excision and repair of deep tissues are necessary. Local anesthesia, of course, should not be used in definitely contaminated wounds or those which by reason of the duration of the injury are thought to be infected.

In wounds received shortly before admission to the hospital the area about the injury should be thoroughly cleansed with soap and water, followed by careful shaving of the involved region. The shaving should not only provide for a clean operative field but should also permit the proper attachment of the dressing without placing adhesive tape over a hairy area A sterile gauze sponge, lightly packed in the laceration, will prevent further contamination of the wound and will check troublesome oozing of blood during the cleanup. Ether or benzene will remove grease and dry the skin surfaces. A second gauze sponge may then be substituted for the first, and the surrounding skin surfaces are painted with half-strength tincture of iodine or other suitable antiseptic followed by appropriate sterile draping. If local anesthesia is used, it should be injected at this stage of the procedure The wound is flushed out by large amounts of normal saline solution. Ether is a suitable cleansing agent if damaged subcutaneous tissue and fat are present. Strong antiseptics must, of course, be avoided. The depths of the wound are explored

The treatment of injuries to underlying tendons or bone is discussed in the chapters on orthopedic surgery. All foreign bodies are carefully sought and removed. Devitalized tissue must be excised and all bleeding points ligated with fine catgut. Care is taken to avoid strangulation of adjacent tissue. Reid used fine silk for ligatures and sutures in injuries of this type, but nonabsorbable suture material should be confined to only the cleanest incision, and the refinements of technic inherent in the use of this type of material must not be abridged.

Fine suture material should be used, care being taken not to place too many buried sutures. The skin margins are loosely approximated with interrupted silk sutures. A pressure dressing should be applied to obliterate dead space and to check any capillary ooze. If the injured part is near a joint, a properly applied splint will promote healing and allay pain.

A prophylactic injection of tetanus antitoxin should be given whenever the conditions under which the injury occurred make tetanus a possibility. The patient should always be skin-tested for sensitivity before the antitoxin is given. The possibility of previous immunization by tetanus toxoid injections must be kept in mind, for the administration of a booster dose of toxoid is far safer than a prophylactic injection of antitoxin. Injuries involving muscle which are contaminated by soil, and especially those occurring in the South Atlantic and Gulf states where gas gangrene is more common, should receive the appropriate antitoxin. Here also a skin test is essential. Antibiotics should be used as an adjunct but never as a substitute for proper local treatment.

CARBUNCLES

Despite the advances made in recent years in the treatment of infection, the prevention and cure of carbuncles has not been altered to any great degree. It is true that early infections situated on the back of the neck or dorsum of the fingers may be aborted by the use of antibiotics, but once the diagnosis of a carbuncle is made, the likelihood is that the infected area will have to be treated surgically just as it was in the past before the introduction of antibiotics.

Lee and Downs' method of crucial incisions made with a sharp knife, extending well beyond the indurated area and dividing the involved tissue into four sections, is still the surgical method of choice. Each of the four flaps is undermined about halfway between the skin and the deep fascia to open all of the infected columns of fat in the carbuncle and thus permit the discharge of pus and release of tension from each focus of infection. As each flap is elevated, strips of petrolatum gauze, or pads of dry gauze if oozing is free, are placed in the defect. Antibiotics are continued and warm dressings are applied for relief of pain and to facilitate the drainage of pus. The gauze is removed within forty-eight hours and the triangles of skin are permitted to fall into the normal position. In small carbuncles it is sometimes possible and desirable to excise the entire involved area.

PILONIDAL CYSTS AND SINUSES

The proper treatment of pilonidal cysts and sinuses was one of the major surgical problems encountered during World War II. A survey conducted in the hospitals of the Army Air Forces in 1944 showed no less than thirteen different methods of treatment. In the larger hospitals entire wards were filled with patients

undergoing treatment for this disabling condition, and in some cases continuous hospitalization for more than a year was necessary in order to effect a cure.

Several conclusions were evident from this survey. The earlier these cases were seen and treated, the shorter the period of disability. The cysts which had been the site of only one abscess were naturally far easier to cure than those which had been acutely infected several times with resulting "sprinkling-pot pattern" of draining sinuses over the sacral region. The greatest deterrent to primary healing was the presence of infection at the time of definitive surgery. The failure to obliterate dead space was a frequent cause of poor healing, and cursory aftercare resulted in many recurrences. Few conditions require the detailed pre- and post-operative care that must be exercised in treating pilonidal cysts.

All infection must be carefully cleaned up before operation is carried out. This means that every abscess and involved sinus must be opened widely. Sitz baths and antibiotics will speed up this phase of the treatment, but several weeks should elapse between the last evidence of local infection and the actual excision of the involved tissue. The best operation for this condition is the simplest. Excision and closure are preferable to more elaborate procedures with extensive undercutting and shifting of flaps.

Larsen in 1947 presented an excellent review of the various types of procedure advocated in the treatment of this condition, with the immediate and late results obtained by each method. In a series of 225 consecutive cases he obtained initial healing in 96.9 per cent following simple excision and primary closure.

The technic, in brief, is as follows: All infection is thoroughly cleared up as outlined above. The patient is placed in the prone position, the operating table is broken in order to flex the thighs moderately on the body, and the buttocks are strapped apart. The operative site is thoroughly cleansed with green soap, ether, and an appropriate antiseptic. Care is taken to prevent contamination of the operative field by the anus. Methylene blue or some similar dye may be injected in a sinus to stain the various tracts but this is not necessary and may be misleading. An elliptical block of tissue is outlined in such a manner that the sites of former draining sinuses and the usual dimple or sinus in the lower midline are incorporated with the excised skin. As a rule, it is not necessary to remove an excessive amount of tissue. If one sinus is at a considerable distance from the other sinuses and is situated far laterally, an extension to this point may be made at right angles to the long axis of the ellipse and the major portion of the intervening skin need not be removed. This will permit coring out the connecting sinus without needless sacrifice of skin and subcutaneous tissue.

Only normal tissue should be divided, and if a former tract is encountered in the dissection this must be incorporated in the tissue to be removed by a wider excision. The margins of the wound should be vertical or directed inward and not slanted downward and outward. The dissection is carried downward to the sacrococcygeal fascia. Bleeding vessels are ligated with fine cotton, silk, or plain catgut, and hemostasis must be complete. The incision is flushed out thoroughly with normal saline solution. The adhesive straps are removed, and the incision is then closed in successive layers with fine suture material as indicated above. The sacrococcygeal fascia is included in the deep sutures. The depth of the incision determines the number of layers necessary, for dead space must not be left (Fig 87).

By placing sutures one row at a time before tying, it is possible to approximate widely separated tissues without undue tension on any individual suture if the but-

tocks are pressed together while each series of sutures is tied. The skin is closed by relatively superficial on-end mattress sutures of cotton or silk. A snug pressure dressing with mechanic's waste is applied. If the postoperative course is favorable and afebrile, the incision should not be dressed for seven or eight days, at which time the sutures may be removed. Healing is promoted by keeping the patient relatively quiet during this period. Activity not only disturbs the incision but increases local sweating with resulting maceration. The bowels should not be moved for several days Antibiotics should be given in adequate doses during the period of healing Care must be taken that there is no overlap of the skin margins, and hairs which bridge the incision and tend to grow into the opposite skin margin must be removed, otherwise a recurrence is likely.

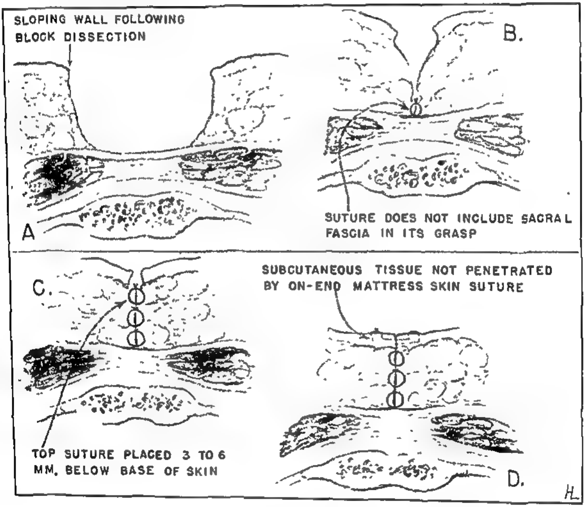

Fig 87—Simple excision and primary closure of tissue about site of a pilonidal cyst or sinus. (After Larsen.)

The *foregoing* procedure gives excellent results in pilonidal cysts of small or moderate size. In neglected cases with numerous sinuses involving a large area, it may be impossible to obtain primary approximation of the skin margins without undue tension with resulting necrosis and separation.

The partial closure method described by MacFee, Mutschmann, and others is of aid in handling these large cysts, and the preoperative treatment is carried out as described previously. Every effort should be made to clean up all infection prior to operation as in the case of primary closure. At operation all diseased skin and subcutaneous tissue is excised. It may be necessary to undercut the skin in the

Fig. 88.—Type of excision required to incorporate all tracts and sinuses in an extensive pilonidal sinus. No effort is made to approximate the margins of the wound, which instead are sutured to the underlying sacrococcygeal fascia. (After Mutschmann.)

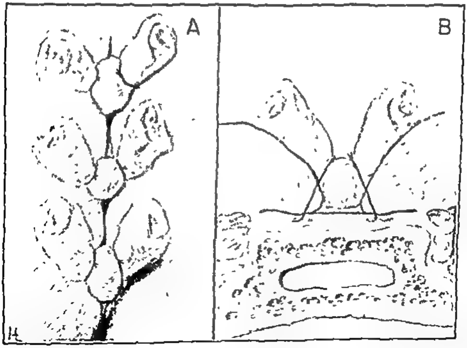

Fig. 89.—Method of partial closure of wound following excision of pilonidal sinus. The sutures may be tied over gauze sponges or threaded through buttons. (After Mutschmann.)

more extensive cases and remove considerable subcutaneous tissue and fat. This does not carry the disadvantage in the partial closure method that it does in the complete closure procedure. In fact, a moderate excision of the subcutaneous fat may facilitate the suture of the skin margins to the deeper structures. (Figs. 88 and 89.)

The incision is flushed out with normal salt solution after careful ligation of all bleeding points. The partial closure is effected by suturing the skin edges to the sacrococcygeal fascia with interrupted silk or cotton. The skin margins are brought as close to the midline as possible without tension. An ellipse of fascia of varying width remains exposed. This area is soon covered by epithelium which grows in from the skin margins. This method requires frequent dressings and close postoperative care. The end result is not perfect anatomically, for the crease between the buttocks is accentuated and carried higher than normal. The ultimate function, however, is good and the recurrence rate is not high.

TUMORS, BENIGN AND MALIGNANT

There is little question as to the proper treatment of benign tumors arising from the skin or tissues immediately beneath this structure. Sebaceous cysts and lipomas should be excised. Warty growths may be fulgurated. Pigmented tumors must be handled with care and excised with sufficient margin to preclude the possibility of a local recurrence if the nevus proves to be malignant. Microscopic examination should be made whenever there is any question as to the type of tumor or the slightest possibility of a malignancy being present. Bleeding points should be ligated with fine catgut or nonabsorbable material, and the skin should be approximated carefully with fine silk or cotton.

The treatment of malignant skin tumors presents an entirely different problem and requires an altogether different approach. The most frequent distinction that should be made lies between basal and squamous cell tumors. A procedure which should prove adequate in treating a basal cell tumor may be insufficient to cure a squamous cell epithelioma. A biopsy should be done to determine the type of tumor. If the lesion is small and so situated that removal of the entire growth with a wide margin is possible, this should be done in preference to excision of a small segment of the tumor. If the growth is extensive and located near important structures, a biopsy of the margin of the ulcer incorporating the junction of the tumor with normal adjacent skin should be carried out. A local anesthetic injected at a distance is satisfactory. The electrosurgical unit may be used to diminish bleeding and possibly minimize the likelihood of spread of tumor cells.

The type of tumor found on microscopic examination will determine the subsequent treatment. If the cells arose from the basal layer and a wide excision has already been carried out, no further treatment will be needed in many cases. If the original tumor was extensive and only a segment was removed for diagnosis, a decision must be made as to whether radical surgery followed by skin grafting or intensive radiation should be used. Both modes of treatment are usually effective in basal cell tumors. If cartilage or bone is involved in the growth, radical excision will be necessary to effect a cure. Fortunately this type of tumor rarely metastasizes to the regional lymph nodes and these need not be excised.

If a pedicle flap is needed, this may be outlined at the time of excision of the tumor and transferred in about ten days. Pedicle flaps serve a twofold purpose in

the treatment of basal cell tumors. These grafts not only facilitate the closure of large defects but also, when brought from another area, have a degree of immunity which delays or possibly prevents local recurrence in some cases of incomplete removal of the primary tumor.

If the biopsy shows squamous cell tumor, a more drastic procedure is necessary. In these cases the part of the body involved will determine to a greater degree the type of treatment to be used. Epithelioma of the lips and buccal mucosa are discussed elsewhere. In tumors on the face a wide surgical excision followed when necessary by a pedicle repair and usually by a block dissection of the appropriate cervical lymph node is the procedure of choice in favorable cases.

When feasible, the primary tumor and the regional lymph nodes should be removed en masse, as advocated by Halsted in the radical cure of carcinoma of the breast. In regions other than the breast this may not be possible.

If the tumor is of a low degree of malignancy with good differentiation and many "pearls," a wide local excision may suffice. If because of the type of tumor or the early removal of the initial growth the regional lymph nodes are allowed to remain, the patient must be kept under close observation in order that an immediate block dissection may be carried out if there is evidence of recurrence in the lymph nodes. In any type of squamous cell tumor except the most benign, a radical block dissection must be done as soon as possible after excision of the primary tumor. The trend in recent years has been to do more radical procedures in the treatment of advanced malignancies. The ultimate worth of the more extensive and mutilating operations must await a longer period of evaluation.

MALIGNANT MELANOMAS

All deeply pigmented nevi and all moles which by reason of their location are subject to trauma should be excised as a prophylactic measure.

Suspicious nevi which appear in childhood should be removed, for pigmented tumors which are excised prior to puberty do not recur.

Certain precautions must be observed in the prophylactic excision of pigmented tumors. The nevus must not be traumatized in any manner during the procedure. On theoretical grounds, intravenous Pentothal Sodium should be the anesthetic of choice, but, if the patient demurs, a carefully administered local anesthetic probably carries a minimum of risk. The hypodermic needle must be inserted at a distance and the procaine should be injected around and not into the region of the tumor. The nevus must not be grasped by an instrument or manipulated in any manner. A sharp scalpel should be used and the nevus must not be coagulated. A margin of 1 cm. should be given the tumor and the full thickness of the skin must be excised. A pathologic examination should be made, for any tumor worth removing is worth examining microscopically. If the microscopic examination should show a malignant melanoma, a second and more radical procedure must be done.

If the patient gives a history of pigmentation of the nevus or recent increased elevation, scaliness, bleeding, or itching, a much wider margin should be given than the 1 cm. described above, for these changes should arouse suspicion of malignant change.

A certain number, fortunately small, will show unmistakable indications of malignancy when first seen. These are usually coal black, fungating, or ulcerated tumors. Adjacent areas of stippling or actual daughter tumors about the primary lesion may be seen. If the tumor is growing very rapidly, the metastases may not show the intensity of pigmentation which is present in the initial lesion. Enlargement of the regional lymph nodes indicates widespread involvement and a correspondingly poor outlook. An x-ray of the chest should be made to rule out blood-borne metastases to the lungs.

If the lungs are uninvolved and the patient shows microscopic or unmistakable clinical evidence of a melanoma being present, a major excision is indicated. A general anesthesia must be administered The primary tumor must be excised with a minimum of 5 to 10 cm of adjacent skin Skin grafting is frequently necessary. The underlying fat and fascia should be removed over an even greater area If the regional lymph nodes are grossly involved, a block dissection of these glands should be made ten or fourteen days later. This interval of time is permitted to elapse in order to allow tumor cells which may be migrating up the lymphatics at the time of the first operation to reach the lymph nodes before these nodes are excised. If the lymph nodes are not involved clinically at the time of excision of the melanoma, the block dissection of the regional nodes should be deferred until five or six weeks after the initial operation.

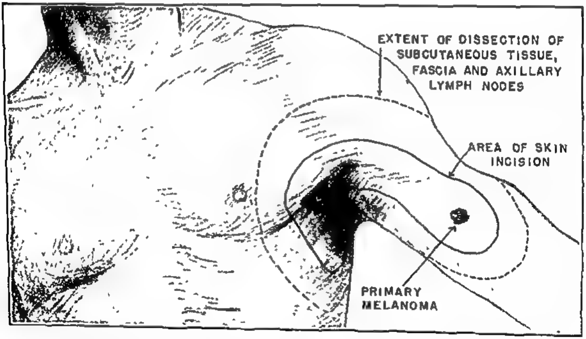

Fig. 90—Method of excision and dissection in continuity which may be used when the primary lesion is situated relatively near the lymph nodes into which the lymphatics drain. (Pack)

In recent years, Pack and his associates at the Memorial Hospital have been carrying out in suitable cases an "excision and dissection in continuity" for primary and metastatic melanomas of the skin. This procedure is based on the principles outlined by Halsted in treating carcinoma of the breast. Halsted's operation entailed removal in one mass of the primary tumor, the adjacent skin, the lymphatics through which the tumor cells would pass, and the lymph nodes into which these lymphatics drained. By applying these same principles, Pack is able, in suitably

situated melanomas, to remove widely the primary tumor as well as the lymphatics and lymph nodes with a large segment of skin, subcutaneous fat, and underlying fascia (Fig. 90).

If a melanoma arises on a finger or toe, the accepted treatment has been to amputate the digit and follow this by a wide dissection of the axilla or groin. This, of course, does not obviate the danger of implants at any level in the extremity as a result of tumor cells lodging in the lymphatics.

In an effort to overcome this hazard, the Memorial Hospital group has carried out more drastic procedures during the past few years. In cases where the primary lesion is situated too distant from the regional nodes to permit "excision and dissection in continuity," interscapulothoracic (shoulder-girdle) amputations have been performed for melanomas of the upper extremity. In the lower extremity, melanomas of the foot with metastases to the femoral and inguinal glands have been treated by disarticulations of the hip joint with retroperitoneal dissection of the iliac and obturator lymph nodes. *Hemipelvectomies (hindquarter amputations)* have been performed which entailed amputation of the lower extremity together with the innominate bone on the involved side. It may be found that operations of this magnitude are not only justified, but indicated, in what would otherwise be a lethal condition, though sufficient cases have not been followed over an adequate period to permit final conclusions at the present time. A procedure as mutilating and disabling as a shoulder-girdle amputation or hemipelvectomy should be buttressed by an impressive five-year-cure rate before its general adoption is justified.

Many melanomas have been treated by radiation but the results have been uniformly discouraging. The only hope of effecting a cure at the present time is *early and definitive surgery.*

The fate of the patient with an early melanoma rests in the hands of the first physician who sees him. Temporizing with such a condition or ill-advised methods of removal make the death of the victim inevitable.

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CHAPTER 14

GENERAL PRINCIPLES OF PLASTIC SURGERY

HARRY J. WARTHEN, JR.

SCOPE OF PLASTIC SURGERY

Plastic surgery has made great progress during the past decade. The large number of wounded of World War II who presented problems in plastic surgery resulted in a better understanding and standardization of treatment than has been true in the past.

Plastic or reconstructive surgery deals with the correction of defects resulting from trauma, disease, or errors of development. While in a broad sense the term may be applied to operations on any kind of tissue, as bones, tendons, or nerves, it usually refers to the correction of defects involving the skin or mucosa either entirely or in large part Plastic surgery formerly was concerned chiefly with the face, though now any portion of the body in which there are defects from injury or illness or from developmental defects may be the site of a plastic procedure.

Among these conditions are wounds of various types, particularly burns produced by thermal, electrical, or chemical injuries as well as x-ray and radium burns; scars and keloids; chronic ulcers; congenital deformities as harelip, cleft palate, syndactylism, malformation of external ear; nevi, hemangiomas, lymphangiomas; crushing injuries involving facial bones; reconstruction of the breast, external ear, nose, eyelids, cheeks, lips; defects of scalp, neck, trunk, and the extremities.

GENERAL PRINCIPLES

The principles of plastic operations involve, first of all, the nutrition of the corrected tissue, and, second, the mechanical reconstruction that will bring the parts as nearly as possible to a normal condition. Operations that apply to particular regions will be discussed in the chapters devoted to regional surgery. There are, however, many underlying principles which must be borne in mind if success is achieved, regardless of what portion of the body is involved.

Plastic operations are of two types: that in which the margins of the wound are prepared for a fresh union and sutured without transplanting tissue or without the intervention of flaps, and that in which flaps or grafts, free or pedunculated, are necessary. The former type is applicable in harelip and cleft palate or in defects which follow a small or narrow injury. Usually after burns or extensive

traumas the resulting deformity is so great that it is impossible to reconstruct the tissues by excision of the affected part and union of the edges of the wound. In such cases recourse may be had to several procedures. One is to undermine the margins of the wound for a considerable distance and determine if the additional relaxation obtained by the undermining will permit approximation of the edges of the wound.

Davis secured excellent results by gradual partial excision of small scar tissue areas and certain nevi. This method is also of value in the removal of tattooed areas. If the area is too broad for total excision and approximation of the edges of the wound, an elliptical segment is excised from the center, the margins of the wound are undermined, and the edges of the wound are approximated. The size of the ellipse should be limited only by the ability to close the margins. After this has healed firmly and the adjacent skin has stretched, which requires from six to twelve months, another section of the area is excised. In this way the elasticity of the skin will permit ultimate approximation of the healthy portion of the skin in a linear scar by gradual traction, which would be impossible if all of the involved tissue were excised at once. In these cases in which the defect or deformity is too great to permit closure by multiple excisions, some form of flaps or grafting must be employed. Multiple excisions should not be used to remove deeply pigmented nevi. These should always be excised with a good margin and an incision should not be made into the tumor.

The operation to be performed depends largely upon the part of the body affected and also upon the function of this region If, for instance, there is a large raw surface on the back of the legs where a scar will not be conspicuous or annoying, the chief problem is to heal the raw surface even if there results a marked scar. It is always desirable, of course, to have as little scar tissue and as nearly a normal skin as possible. If, however, a large defect on the body or limbs can be so healed as to give the patient a stable scar without discomfort or interference with function, the main indication will have been fulfilled and prolonged and complicated operations to render the scar less prominent will hardly be justifiable.

Methods that not only restore function but remove deformity as well are to be desired. Whole skin, as a free graft or with a pedicle flap, usually gives the best results from every standpoint. The graft should match the texture of the skin around the defect as far as possible. As a rule, skin taken from the region of the deformity more nearly corresponds to the texture of the skin about the defect than that taken from some distant part. Sometimes, however, it is impossible to obtain flaps near the defect and they must be transplanted from a distance.

When the appearance of the scar is of secondary importance and the healing of the wound is the main object, thin grafts of epidermis in sheets or cut into small seed implants, small deep grafts, or "postage stamp" grafts are very satisfactory When properly applied on a clean field, such grafts usually take without difficulty, and large raw surfaces that would require months to epithelize or would perhaps never heal are closed in ten days to a few weeks. These grafts would be universally used instead of free transplants of whole skin or flaps except for two disadvantages: the scar resulting is conspicuous, for the skin of the scar does not appear to be normal, and there is often a marked tendency to contraction after their use The

contraction after an injury to the skin of the face, for example, is not in epithelial elements of the skin but in connective tissue that underlies the epithelium. In other words, the contraction lies in what corresponds to the corium, which is composed largely of connective tissue and on which rests the epithelial layer. If, in the healing process, this is made up of scar tissue, particularly of the dense scar tissue that follows a burn, contraction deformity will probably result even though the surface may be covered by healthy epithelium. It is contraction in this subepithelial layer that produces the striking deformities following burns of the face or hands.

If, then, a scar contraction is excised and thin grafts of epidermis are used to heal over the surface, the contraction will almost invariably recur. In order to avoid this, it is necessary to use thick split or full thickness grafts which include not only the epidermis but normal healthy corium that does not contract.

The general health of a patient who requires plastic surgery is of utmost importance. Before any major plastic procedure, a complete history should be taken and a complete physical examination made, as well as the customary laboratory work including serology, urinalysis, hemoglobin determination, serum protein, red and white blood cell counts, blood smear, differential counts, prothrombin and clotting time. Other special laboratory work may be suggested by the history or physical examination. Such conditions as hypoproteinemia, secondary anemia, syphilis, active otitis media, or any other acute infection, malnutrition, or blood dyscrasias are definite contraindications to an immediate plastic operation, particularly in children. Before operation ample opportunity should be given for scar tissue to contract, and its blood supply should be improved by exercises and massage. Many operations followed by poor results may be avoided if these conditions are recognized Time will be gained in the end by improving a poor surgical risk through every available means.

Asepsis, gentle surgery, proper pressure dressings, immobilization, and detailed postoperative care are all important factors. If antibiotics are used and the patient's general health is good, with normal tissues and the defect so situated that it may not readily become contaminated, infection rarely occurs. In certain locations, as about the mouth, anus, and perineum, infections are occasionally unavoidable Concentrated compound tincture of benzoin applied over fresh incisions, especially about the lips, nose, face, and mouth, lessens contamination and also acts as a splint. Collodion may be used in the same manner after removal of sutures. Tissues that have a poor blood supply due to extensive undermining, tension, or scar tissue are more prone than normal tissue to infection. Hematomas invite infection. If infection does develop, the usual methods of combating it in other types of surgery should be carried out: namely, antibiotics, improvement of the general resistance of the patient, drainage of accumulations of pus with or without irrigation of the cavity, early removal of infected sutures, and hot wet dressings. The addition of about 20 per cent glycerin to the usual solutions for hot wet dressings (saturated boric acid, strong magnesium sulfate. normal physiologic up to 2 per cent sodium chloride) is valuable, as it does not produce maceration of the skin, allows ample drainage, and tends to diminish excessive granulation tissue. Cod liver oil, 5 to 10 per cent balsam of Peru in castor oil, and scarlet red ointment are effective in stimulating healing after the acute infectious process has subsided

Pyocyaneus infections occur frequently and are treated by wet dressings of 0.5 to 2 per cent acetic acid changed frequently and continued over a period of twenty-four to seventy-two hours. A Murphy drip containing dilute acetic acid is a convenient way of controlling pyocyaneus infections It is felt by some that an acid media merely decolorizes the characteristic blue-green color of the drainage. Be that as it may, the drainage lessens and appears less significant after the use of acetic acid. The more severe superficial infections such as the now rare erysipelas and those associated with streptococcus, lymphangitis, and cellulitis quickly respond to appropriate antibiotics. If sloughing occurs, the dead tissue should be cut away as soon as a definite line of demarcation has formed. Hydrogen peroxide facilitates the cleansing of infected and sloughing surfaces and, diluted with equal parts of water, is also a very good mouthwash after operations within the oral cavity.

A point that cannot be stressed too much is the control of hemorrhage. Blood clots beneath a graft often will cause all or a large portion of it to die and will, in addition, invite infection Hemorrhage occurring at the time of operation is controlled by clamping and twisting small vessels and by ligating larger vessels with very fine catgut. Oozing surfaces are checked by firm pressure with hot saline compresses. Sometimes a useful procedure is to coagulate the bleeding point with the electrosurgical unit, but the coagulated area must be minimal. As a hemostatic agent Adrenalin should be used with caution because of the possibility of secondary bleeding. Topical thrombin is of value in the presence of persistent oozing. As far as practical, ligatures and any other means of controlling bleeding which produce additional foreign bodies or an increased tissue reaction are to be avoided in the bed of a wound that is to receive free skin grafts. Whenever ligatures are necessary, very fine silk or 0000 plain catgut is the ligature of choice. A properly applied sea sponge or mechanic's waste dressing immobilized by an elastic bandage will produce uniform pressure over the entire area and will largely prevent oozing beneath grafts and undermined wound margins Secondary hemorrhage is treated by exposing, clamping and ligating the bleeding vessel, removing the blood clots, cleansing the wound with normal saline solution or a mild antiseptic, and reapplying a pressure dressing. Hematomas that develop from oozing should be opened, the clots removed, and the wound cleansed and redressed. For persistent postoperative bleeding not controlled by the above measures, general treatment for prolonged bleeding must be used. The administration of calcium, vitamin C, vitamin K, and other possible deficiency factors seem more effective When these measures fail, transfusions of whole blood or certainly recently drawn blood are indicated.

The principal factors in preventing large deforming scars are gentle handling and complete relaxation of tissues, prevention of infection and hematomas, clean incisions made at right angles to the surface of the skin, careful suturing tending to slight eversion of the skin edges, immobilization of dressings with even and proper pressure (as by mechanic's waste) so applied as to produce no tension on the wound edges, the use of elastic bandages, early removal of stitches, as well as other painstaking details.

Incisions should be made parallel to Langer's lines of cleavage of the skin (Figs. 91-93). An appreciation of the constancy of these lines of tension is emphasized by the early Byzantine Christian mosaics recently discovered in Istanbul and

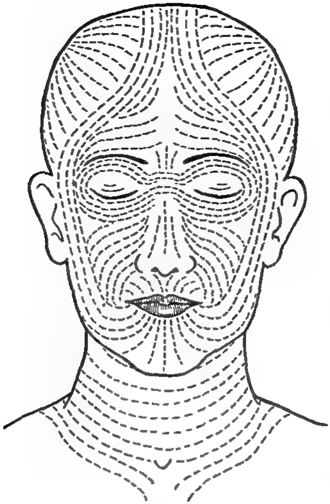

Fig. 91.—Langer's lines of tension of the skin of the face (Redrawn from Pick.)

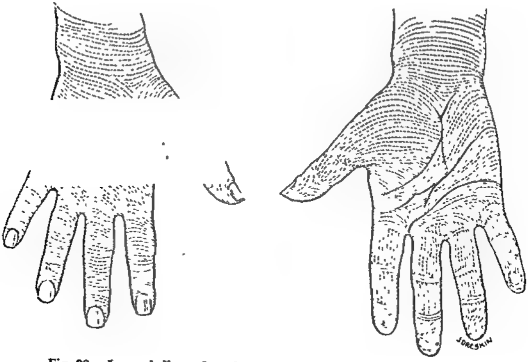

Fig 92.—Langer's lines of tension of the surface of the hand. (Pick.)

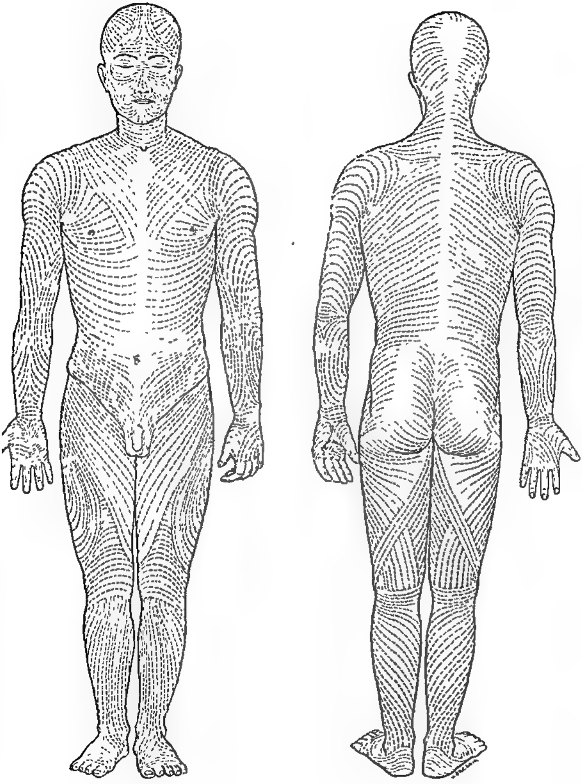

Fig. 93 —Langer's lines of tension of the skin of the trunk, head, and extremities (Pick.)

photographed by Kessell. The general course of the connective tissue bundles of the corium determines the direction of these linear clefts. If the incisions follow these tension lines, there will be little gaping of the wound or spreading of the subsequent scar. If the incisions are made across these lines, wide gaping will occur and a broad scar will result. The intelligent use of radium and the roentgen ray is often very helpful in preventing hypertrophied scars and keloids in patients who are known to be subject to these disfigurements.

Skin grafting is one of the most important procedures in plastic surgery. Grafts taken from another of the same species may seem to flourish at first but usually slough off or are absorbed in the course of time. Grafts usually live when taken from the patient's own body. Grafting from one individual to another rarely proves successful.

Trusler and Cogswell state that, from their experience and a critical survey of the literature, they are led to believe that most reports of success with homotransplants of skin arise from the fact that these grafts can and often do adhere and appear to grow for several weeks. In their cases, however, such grafts have not remained viable and their ultimate fate has been a more or less delayed slough. Healing by scar tissue formation eventually occurred. These observations are in agreement with reports of Longmire and others. Padgett believed that autotransplantation of skin usually succeeds and that syngenesiotransplantation of skin is theoretically improbable except in identical twins where it is theoretically probable and clinically has occurred. He has reported a successful growth of skin transplants from one identical twin to another. Converse and Duchet reported a similar case. Experimental work upon animals and theoretical reasoning argue against the blood grouping of an individual playing a role of any essential significance in the homotransplantation of skin. The simultaneous use of cortisone does not aid in the use of homografts.

PLANNING OPERATIONS

Photographs, models, cases, drawings, and accurate measurements of cases are of great value as records for later comparison and likewise are helpful in planning the best operative procedure. They also may be invaluable from a medicolegal standpoint. A flexible metal rule, calipers, lead foil, patterning material such as perforated cellosilk or cellophane, and a means of outlining incisions are indispensable. One of the various antiseptic dyes (as 5 per cent brilliant green in an alcoholic solution) on a sterile applicator stick, or a fine drawing pen can be used to mark out prospective incisions.

ANESTHESIA IN PLASTIC SURGERY

A considerable number of the less extensive plastic operations can be done under local anesthesia, using a 1 per cent procaine solution to which has been added 2 to 4 drops of 1:1,000 Adrenalin chloride solution to each 30 c.c. of the procaine solution. Definite contraindications to local anesthesia are lack of cooperation by the patient, as with infants and children, interference with the accuracy of operation by the distortion of the tissues, and impaired circulation from the edema produced by the infiltration.

As a rule, the anesthesia indicated in plastic surgery on adults corresponds to that used in general surgery. A greater degree of selection is necessary in carrying out plastic procedures on children.

The basic principles of good anesthesia are the same regardless of the type of surgical procedure indicated, and these include:

I. Preoperative evaluation of the patient
 a. Activity
 b. Drug idiosyncrasies
 c. Anesthesia preferences
 d. History of previous anesthesia
 e Physical examination
 f. Laboratory work
 g. Weight

II. Preoperative medication
 a. Evening sedation
 b. Preoperative sedative
  1. Barbiturate
  2. Narcotic
  3. Autonomic blocking agents—atropine, scopolamine
 c. Rectal Pentothal

III. Choice of anesthesia

IV. Control of airway
 a. Anoxia
 b. Carbon dioxide elimination
 c. Finger-tip control of plane of anesthesia

V. Control of heat loss or retention

VI Shock
 a. Blood
 b. Intravenous fluids

Regional or general anesthesia may be used as the situation demands. Surgery of the head and neck presents major problems in plastic cases. The basic principles of anesthesia described above are best carried out by endotracheal anesthesia with the Stephen's nonrebreathing, nonresisting valve in children for surgery involving the face, neck, and oral cavity. This avoids the more usual, but less physiologic, open drop ether and insufflation ether technics. Many of the principles and technics outlined above are discussed in greater detail in later chapters.

Preoperative medication is most important; if properly administered, it will avoid psychic trauma that otherwise may scar the personality for years, and it will allow for ease in future handling of the patient. The basal metabolic rate is lowered, fear is allayed, induction is made easy, the secretions are reduced, and reflexes are blocked. The fear of anesthesia which many adults have today frequently dates back to an unpleasant experience in childhood. In children, it is seldom

necessary to give a hypnotic the night prior to operation; however, if it is desired, one of the quicker acting barbiturates may be used.

In children under 50 pounds of body weight, Pentothal Sodium may be given rectally. Atropine in the desired dosage is given forty-five minutes preoperatively. The dosage is 20 mg. (0.2 c.c.) of a 10 per cent solution per pound of body weight given thirty minutes before operation. A No. 16 urethral catheter is lubricated and inserted 5 cm. within the rectum. The buttocks are taped together. After the desired dosage is given, the catheter is cleared with 2 c.c. of air and clamped. Leaving the catheter taped in place prevents the child from expelling the medication. The child falls asleep within five to fifteen minutes. This is only a basal hypnotic, and a supplemental anesthetic must be given to secure anesthesia.

Once the child is asleep, the anesthetist must assume protective control of the patient. For safe anesthesia, an absolutely patent and secure airway is mandatory. This is best obtained by the use of an endotracheal tube. Because of the frequent objections raised to the intubation of children, this technic will be discussed. Walker feels that the complications of this procedure are due to faulty technic rather than to the intubation itself.

A child should be intubated in the lower second plane of anesthesia with a nonirritating plastic endotracheal tube. Although some anesthetists advise that a water-soluble anesthetic jelly be used on the tube, no lubricant is actually necessary. In order to assure that the tube is the correct size, it must be selected only after the larynx has been exposed. To accomplish an atraumatic intubation, the tube is inserted with a twisting motion. Once the tube is in place, it should be checked to ascertain that it is not in too far. In children the trachea is short and the tube can easily be passed into the right main bronchus. The lungs are checked to see if they inflate easily; if they do not, the tube is withdrawn until easy inflation occurs. The tube is then fastened securely in place in such a manner as to avoid distortion of the mouth and to be accessible to the anesthetist. With the exception of the endotracheal tube, the anesthetist may then remove himself and his equipment from the operative field. He must, however, remain in position to watch and control the patient's respiration.

Extubation is equally as important as intubation. "Bucking on the tube" (coughing with the larynx open) should be avoided. Unless secretions are present, endotracheal suction should not be done. Secretions should be removed from the pharynx and nasopharynx and the child should be well oxygenated. Upon expiration, the tube is quickly removed and oxygen is given by mask. Adherence to this technic will avoid the possibility of laryngeal edema

Ether, cyclopropane, and Pentothal Sodium are all good anesthetic agents in children; however, the most physiologic method and the one involving the least cumbersome apparatus is a nonrebreathing, nonresisting technic. Stephen's valve, a more recent modification of the Leigh valve, is an improvement over the earlier Ayre method. A child cannot handle the regular circle filter anesthesia machine because of the high resistance; the patient works hard, soon builds up a carbon dioxide excess, and becomes exhausted. The Waters to-and-fro cannister is cumbersome, must be changed frequently so that the child will not build up heat, and there is the danger of inhaling dust.

the suture material over rubber tubing, soft metal plates or buttons in order to prevent a line of pressure necrosis. In general, the best needle is a small, curved (or half-curved), cutting-edge needle. One of the methods of suturing is illustrated (Figs. 94 and 95). No suture should be tied tightly enough to cause blanching or other evidence of strangulation of the tissues. A certain amount of tissue reaction with swelling follows any operation, and allowance must be made for this. The early removal (two to four days) of sutures in operations about the face is imperative in order to prevent suture marks and to obtain the best cosmetic result. The application of flamed adhesive strapping or flexible collodion will tend to prevent spreading of the incision after removal of the sutures.

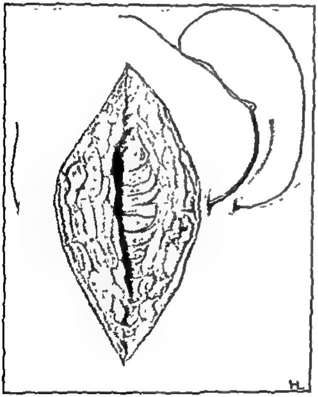

Fig 94

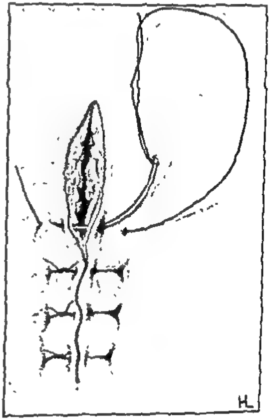

Fig. 95

Figs. 94 and 95 —McMillen on-end mattress suture.

DRAINS AND DRESSINGS

Careful hemostasis largely obviates drainage, though in some instances drains must be inserted to prevent hematoma formation. Small strips of rubber dam may be placed beneath pedicle flaps and removed in two or three days.

Suture material may be attached to the drain, which can then be withdrawn by making traction on the long end of the suture previously carried to the margin of the dressing. This permits removal of a drain without disturbing the pressure dressing.

Simple face wounds are frequently not dressed but merely covered with boric acid powder or a concentrated preparation of compound tincture of benzoin. Wounds close to the eyes may be covered with sterile petrolatum or some mild anti-

septic ophthalmic ointment, such as 1:10,000 Metaphen with or without 2 per cent Butyn. In certain instances hot wet dressings of boric acid or normal saline solution containing 20 per cent glycerin tend to relieve congestion and prevent infection.

Pressure dressings with properly shaped marine sponges or mechanic's waste are most helpful. They should be applied carefully, any uneveness or excessive pressure being avoided, and should overlap the entire perimeter of the wound margins by at least 2 or 3 cm. In dressing free grafts, Xeroform or Bettman's scarlet red gauze may be applied smoothly next to the wound. This is accurately covered with a few layers of gauze and a sterile wet marine sponge, or carefully shaped mechanic's waste dressing is applied. Over the pressure dressing a layer of gauze is placed and the entire dressing is then securely fastened with strips of adhesive plaster to prevent slipping. More gauze is applied and this dressing is covered with an encircling elastic bandage. Immobilization of the part should be carried out when feasible.

A *useful method of immoblizing small deep (Davis) or "postage stamp"* grafts is to apply a single layer of coarse gauze snugly over the recipient area and to attach the circumference of the gauze to the surrounding normal skin with collodion. If the granulations are moist or appear to have excessive secretion, the area may be left open for twelve to twenty-four hours or longer if desired. A cardboard box or other similar barrier may be used to protect the newly grafted area from contamination If the granulations appear entirely healthy, an immediate wet dressing may be applied to the grafted area.

Scarlet Red and Bettman's Gauze

If it is anticipated that a Bettman's gauze dressing will be used at operation, it is desirable to determine if sensitivity is present prior to operation. This may be done by applying the ointment beneath an occlusive dressing over a sensitive area, such as the inner surface of the arm, and checking the skin for any evidence of reaction after two or three days. Sensitivity may be due to the scarlet red or to the oxyquinoline sulfate or chlorobutanol which are also contained in Bettman's gauze. Scarlet red stimulates epithelial proliferation and is somewhat astringent. Weeping areas or superficial excoriations frequently heal more promptly under simple 5 per cent scarlet red ointment than when the more complicated Bettman's formula is used.

POSTOPERATIVE CARE

From two to six weeks after complete healing of many plastic and reconstructive operations, the application of cocoa butter or olive oil, followed by a gentle circular massage with the finger tips for several minutes daily, is beneficial in improving the circulation, in softening scars, and smoothing out any irregularities. Active and passive motion and, later, individually directed exercises are valuable aids in restoring function, particularly when an extremity has been operated upon and immobilization used. Scars and the thinner skin grafts do not contain sebaceous glands, and consequently their surfaces are dry. When this dryness is excessive, cracking, scaling, and other signs of irritation may be prevented by cocoa butter, olive oil, or some similar oily preparation.

CLOSURE OF DEFECTS

Many of the procedures used to close defects have become classical. The chief methods are given in the following illustrations, which are self-explanatory. The time-tested methods of Szymanowski are ingenious and usually satisfactory. Simple relaxation incisions parallel with the wound will be all that is necessary in some cases.

Methods of Closing Triangular Defects

It should be noted that the result is usually more satisfactory in the drawings depicting the closure of defects than in actual practice. Care must always be taken that sutures approximating the tips of flaps incorporate a minimal amount of tissue, *otherwise the end of the flap will slough. A wide variety of closures is available* (Figs. 96-104).

Fig. 96.—Closure of a triangular defect by the method of Jäsche.

Fig. 97.—Closure of a triangular defect by the method of Szymanowski.

Fig. 98.—Closure of a triangular defect by the method of von Ammon.

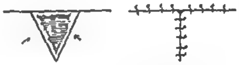

Fig. 99.—Closure of a triangular defect by the second method of Szymanowski.

Fig. 100.—Third method of closure of triangular defect according to Szymanowski.

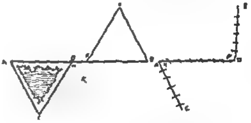

Fig. 101.—Closure of a triangular defect by the method of Burow.

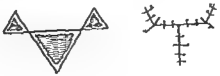

Fig. 102.—Second method of closure of triangular defect according to Burow.

Methods of Closing Oval and Circular Defects

Defects of this type may represent decubitus ulcers, which always present problems in closure. An oval defect can be closed by any one of a number of different procedures. Lisfranc's method is simple and useful (Figs. 105-113.)

Fig. 111.—Closure of circular defect, by first method of Szymanowski.

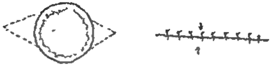

Fig 112.—Closure of circular defect by second method of Szymanowski.

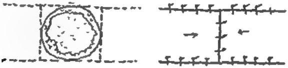

Fig. 113 —Closure of circular defect by third method of Szymanowski.

Fig. 114.—Closure of quadrilateral defect by method of Cole.

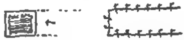

Fig 115 —Closure of quadrilateral defect by first method of Szymanowski.

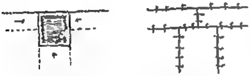

Fig 116 —Closure of quadrilateral defect by second method of Szymanowski

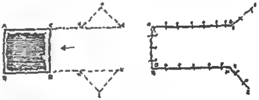

Fig. 117 —Closure of quadrilateral defect by method of Burow

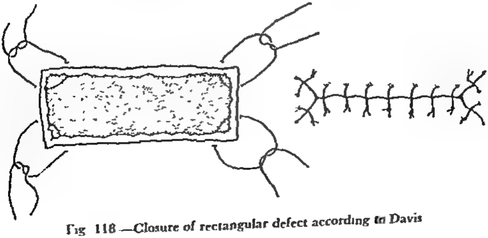

Fig 118 —Closure of rectangular defect according to Davis

Methods of Closing Quadrilateral Defects

These defects may be closed by undercutting, sliding, and several types of relaxation incisions. Special care must be taken in placing sutures in the corners of the flaps. (Figs. 114-118.)

Closure of Defects by Radical Undermining

Otto reported 11,000 battle wounds closed by excision, radical undermining of the margins, and use of marginal flaps when necessary. Extensive undermining of wound margins, if done in the proper plane, will permit approximation of wide

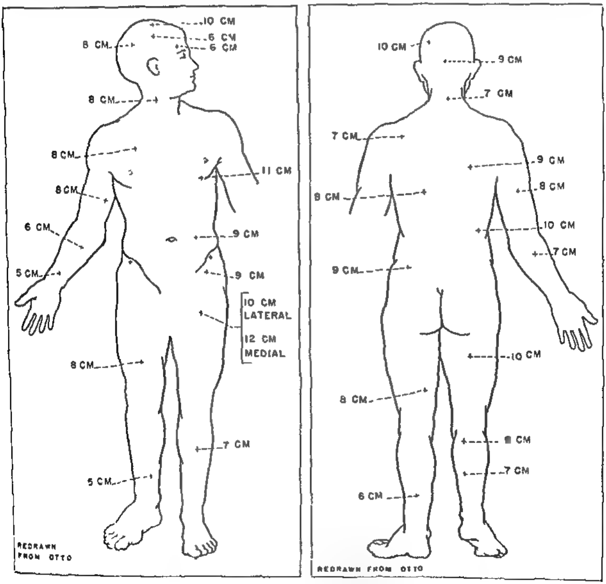

Fig 119—The degree of undermining possible in various parts of the body is indicated by the above estimates (Otto)

defects (Fig. 119). The dissection is carried out beneath the subcutaneous fascia and fat under direct vision by divulsion with scissors. Perforating vessels *must not* be injured (Fig 120) Otto used marginal flaps which were rotated across the wound in defects which were too large to permit closure with simple undermining (Fig. 121). The included angle in these flaps should not be less than 20° or greater

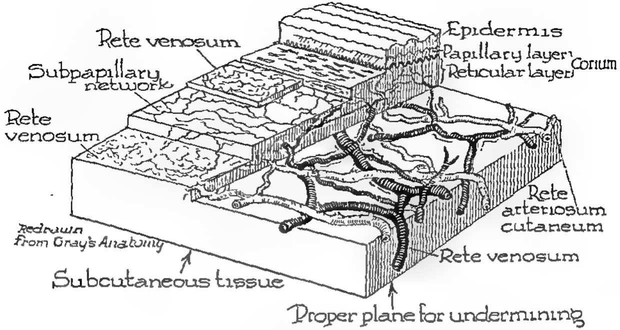

Fig 120—The proper plane for undermining is indicated This should be beneath the subcutaneous fascia and fat with preservation of the perforating vessels.

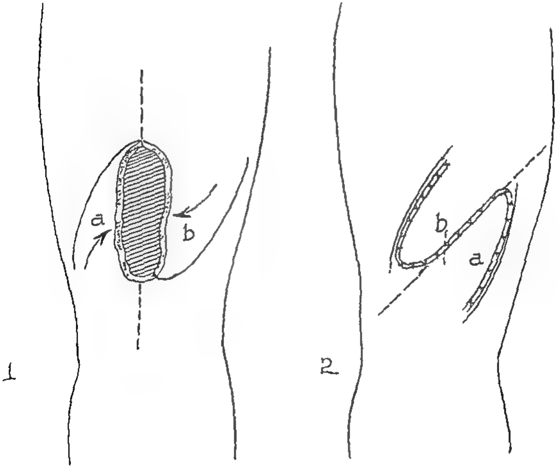

Fig 121—Interpolated marginal flaps with transposition (Otto)

than 45°. Tension sutures are spaced 3 to 4 cm. apart and include 2 to 4 cm. of the flap. Skin approximation sutures are spaced 1.5 cm. apart with alternating on-end mattress type sutures to prevent inversion. Compression bandages with elastic wrapping are applied to control oozing and splint the tissues.

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CHAPTER 15

THE CAUSES OF CONTRACTURES; THE TREATMENT OF SCARS; WEBBED FINGERS; KELOIDS

HARRY J. WARTHEN, JR.

CAUSES OF CICATRICIAL CONTRACTIONS

Many plastic procedures are designed to correct prominent scars which have resulted from excessive cicatricial contraction. Frequently plastic operations are marred by the subsequent appearance of excessive contractures in the scar. Therefore, it is important to consider the fundamental causes of cicatricial contraction and the methods by which this undesirable sequel of operations and injuries may be obviated.

The histologic examination of any cicatricial contracture on the surface of the body often shows an epithelial covering that is not especially abnormal. In retracted scars about the face and neck which are common after burns, the epithelial covering is practically normal, but the contraction is due to the scar tissue beneath (Fig. 122). The maximum contraction usually occurs after the surface has healed and is entirely covered with epidermis When the histologic structure of a contracting scar is compared with a scar in which there is no contraction, it is seen that there is no essential difference (Figs 123-126) The epidermis is apparently normal in both scars. The underlying connective tissue appears essentially the same and gives no clue to the cause of the contracted scar.

A scar consists of connective tissue, which is low in the order of tissues and is able to survive under conditions which would be fatal to a more highly differentiated tissue. The different tissues have varying capacities for surviving injuries and for repair. The delicately constructed and more recently evolved cortical brain tissue repairs not at all, whereas connective tissue, one of the primal tissues, repairs readily. When conditions, either from toxic or traumatic injury or from lack of nutrition, are such that more highly differentiated tissues cannot survive, connective tissue often may live.

If a granulating surface persists for a long time, there is a tendency for an excessive amount of connective tissue to form as the result of infection and trauma to the soft granulation tissue If this raw surface is covered with epithelium, the graft acts as a protection from further trauma and the formation of scar tissue is lessened. After scar tissue has formed, however, the epithelial covering does not prevent contraction.

If a cicatricial contraction of the skin is to be corrected, a thick graft should be used. Thin grafts do not, as a rule, prevent current contraction, though they may mitigate it.

The causes of cicatricial contraction may be classified as direct or indirect. The direct cause is a toxic substance which is chemical and consists of products formed outside the cells of the body, as from bacteria, or produced within the cells as when they are affected by radiant energy. The most frequent direct causes of cicatricial contraction are from toxic products resulting from burns, chemicals, bacteria, carcinoma, trauma, and radiation. The proliferation of the endothelium with occlusion of the blood vessels following x-ray and radium burns diminishes the blood supply and results in large amounts of scar tissue replacing the more highly differentiated cells.

Fig. 122—Frances K. Deformity from cicatricial contraction of the left side of neck and the left pectoral region

Indirect causes of cicatricial contraction include the general disposition of the individual toward scar tissue formation, the portion of the body affected, lack of proper blood supply, the quantity of scar tissue, and the absence of strain or tension on the scar. Longitudinal scars over flexor surfaces tend to contract, whereas transverse scars in these locations do not. Scar tissue tends to contract where there is no strain on it and to stretch when there is tension.

Avoidance of the above direct and indirect causes, in so far as it is possible, will result in a corresponding reduction in cicatricial contractions.

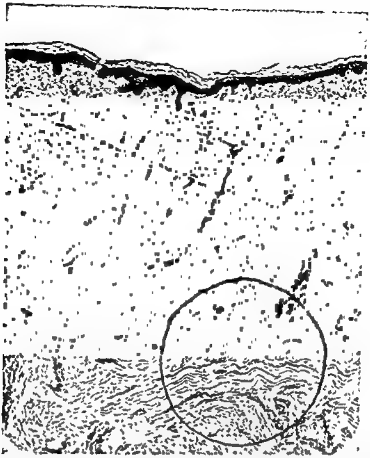

Fig. 123.—F. K. A section from the upper pectoral region of a contracting scar, showing the epidermis practically normal with connective tissue arranged in dense columns in the upper portion of the photomicrograph and in wavy bundles in the lower portion (×60)

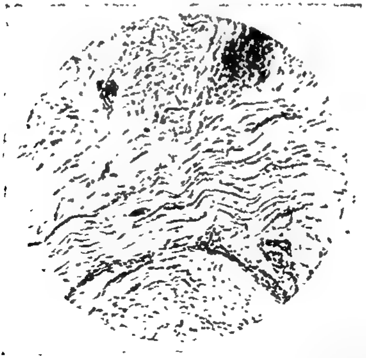

Fig. 124—F K The connective tissue from the lower portion of the preceding figure, showing the wavy fibers of the connective tissue with regions of leukocytic infiltration. (×150)

Fig. 125.—Mrs W. E. G. Noncontracting scar from the abdomen Note the apparently normal epidermis and the wavy connective tissue ($\times$60.)

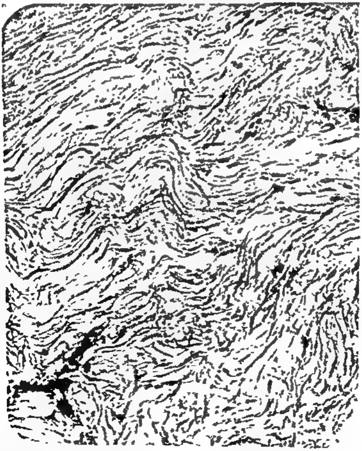

Fig. 126.—Mrs. W. E G. Higher power view of the connective tissue shown in the preceding photomicrograph The fibers of the connective tissue are fine, lacelike, but rather dense. ($\times$150.)

GENERAL CONSIDERATIONS IN TREATMENT OF SCARS

A large proportion of the acquired deformities that the plastic surgeon ha treat is due to scars, which may be deforming in appearance and interferin function. In this section, various methods of treating scars and keloids wil described. A deep scar on the forehead is disfiguring, but does not interfere v function. On the other hand, ectropion of the lower eyelid or lip is both a fu tional and a cosmetic handicap. A scar may limit the motion of joints and tend retard and distort development. It may be painful, harbor infection, or be the of recurring ulcers which often develop into malignancy. The presence of any all of these conditions makes treatment imperative. Recent scars usually impr with time, and this change is aided by massage, exercises, and measures institu to improve the general health. *For this reason it is usually advisable to wait u the scar is from four to eight months old before operating upon it.* Need operations are thus frequently avoided and necessary operations made less exten with better results. In hypertrophied scars, the skillful use of radium and x- will soften the scars and allow greater relaxation of adjacent tissues.

Smooth Scars

Scars which are smooth, soft, and stable are not greatly improved by operat measures, especially if they are extensive and inconspicuous. Excision and graft will sometimes be very unsatisfactory. The graft may become pigmented or pres a different texture from the adjacent skin, and in the donor site of the graft additional scar is produced. The Davis method of gradual partial excision may of value in correcting this type of scar.

Depressed Scars

Of the many methods of correcting a depressed scar, the basic principles a excision, when practical, complete relaxation of the deeper tissues, and accura closure in layers. Davis found it advantageous, where the scar was comparative narrow, to use the deeper portion of the scar, after the epidermis had been excise as a buttress over which to close the skin margins.

In plastic work where the full thickness skin graft, the pedicle flap, or the sli ing flap method is used, a depressed scar along the line of union adds greatly to th deformity no matter how accurately the skin incision is made and sutured. there is a depression and a groove, the scar will spread and become very conspicu ous If there is the slightest tension and the sutures are improperly inserted, thoug the immediate effect may appear satisfactory, as healing and contraction take plac it will be seen that the scar becomes wider and more depressed. The shadow created by depressed scars of the face accentuate the disfigurement.

Esser has laid particular stress upon this occurrence and calls attention to th importance of building up the underlying fat and fascia before suturing the skin This may be done by inserting the sutures so as to catch a small margin of the ski and a deep bite of the subcuticular tissue on each side of the wound, thus approxi mating the subcuticular tissue firmly. If the tension is considerable or the desira bility of an exceedingly small scar great, it is best to undercut the subcutaneous fa and fascia on each side of the wound and bring the fat and fascia together by fine

silk, cotton, or catgut sutures, so forming a slight ridge just under the line where the skin is to be sutured (Fig. 127). This procedure will make the line of incision apparently bulge a little, but, as healing and contraction occur, the ridge will disappear and the scar will be on the normal level of the skin instead of being depressed and contracted. This is a highly important point when excising any scar that has been depressed and is adherent to the tissues underneath. If the depression is too great to be corrected in this manner, there should be transplanted a small amount of fat, preferably on a pedicle from the undermined skin in the region of the wound. If necessary, a free transplant of fat from the thigh can be used.

Fig 127.—The method of Esser for preventing a sunken scar. The subcutaneous fat and fascia are so incised as to form a roll in the middle of the wound.

Unstable Scars

When extensive wounds, especially following burns, heal slowly, unstable scars usually follow. These scars are most common in regions where the loss of skin surrounds and compresses an extremity. The epithelium is very thin, the circulation is poor, the slightest trauma produces a break or blister in the epithelium, and ulceration follows. Since the circulation is poor, infection frequently develops. The instability of these scars often impairs function and sometimes actually produces invalidism. In the treatment of such scars, the infection must be cleared up, the part affected is put at rest, and the general health is improved as much as possible. A high vitamin diet should be given, and blood transfusions when indicated. Partial or complete excision of the unstable scar with the transplantation of a stable form of skin graft is the best procedure. In an extensive constricting type of unstable scar, as, for instance, on the leg, incisions may be made longitudinally down to the fascia Davis' method is to use three incisions in the extremity equal distances apart. The length of these incisions will depend upon the size and extent of the constricting scar. This method of producing relaxation results in gaping wounds corresponding to each incision In suitable cases grafts may be placed on these gaping wounds immediately In many cases there is so much destruction of the underlying tissues from long-standing pressure that immediate grafting is unwise on account of the poor circulation. Under these circumstances the wounds are not grafted until they have partly filled in with healthy granulation tissue and the circulation has improved Care must be taken that more scar tissue does not have time to form during this interval. The type of graft used may vary according to the case. The so-called pinch graft and the thick split skin grafts have proved satisfactory.

In constricting scars which encircle an extremity, skin grafting may be avoided and a good end result achieved by the use of one or more "Z"-plasties which break the line of constriction and increase the circumference of the part.

A scar ulcerated for years must be regarded as a potential source of malignancy and should be treated by radical excision. When true malignancy does occur, it may begin in several apparently independent areas. Microscopically, it usually shows a low grade of malignancy and metastasizes slowly. The duration of the scar

rather than the age of the patient will determine the time of appearance of the malignant degeneration. A young person with a long-standing unstable scar may develop an epithelioma at an early age.

Scar Contractures

In spite of the most careful treatment, scar contractures frequently follow severe injuries or burns. Much unjust criticism is often made of the original treatment when such scars result. It is more important to save the life of the patient

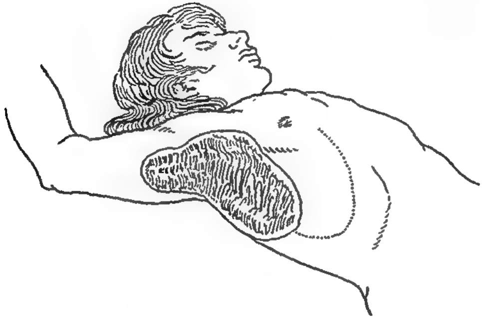

Fig. 128.—Outline of pedicle flap from anterior and lateral chest wall to cover denuded axillary apex.

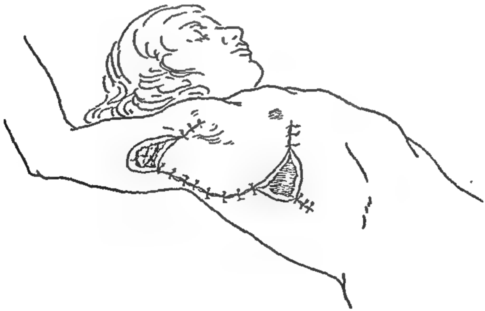

Fig 129.—Transplantation and suture of flap outlined in Fig 128

after severe trauma than to prevent contractures. The release of contracted areas is important at all ages in order to prevent deformity and impaired function. In infants and children or even in young adults who have not completed their growth, the tension and pressure of scar tissue contractures often distort the normal growth

of bone and other tissues. Shortening of the extremities as well as varying types of postural deformities can thus result. If a deformity due to contracture persists over a period of years, marked atrophy of bone and soft tissues will occur. If, however, the deformity is corrected, much atrophy can eventually be overcome. Contractures may develop in any part of the body in spite of the greatest care taken during the treatment of the original wounds. They are especially prone to occur around joints, the most common sites being in the region of the axilla, fingers, groin, knee, neck, and elbow. The prevention of contractures can best be accomplished by promoting rapid healing and early return of function. Blair and Brown recommend daily hot saline baths and the grafting of raw areas as rapidly as possible. After the raw surfaces have healed, contractures may be benefited by massage, exercise, and other physiotherapy measures.

The ideal procedure for correcting contracted scars would be the complete removal of the scar tissue, followed by closure of the normal skin margins. This procedure, however, is seldom possible, as the resulting defects are usually too large to allow closure. Under these circumstances, skin may be grafted or adjacent flaps shifted into the defects (Figs. 128 and 129). Single or multiple division of contracted scar bands, without the placing of grafts on shifting flaps, followed by overcorrection, is rarely successful, and the contractures usually recur.

Use of Z-Plasty

Davis has called particular attention to a method of relaxing scar contractures by the Z or reversed Z-type incision, stressing the use of adjacent scar infiltrated tissues (Fig. 130). Many contracted scars may be corrected by this method where

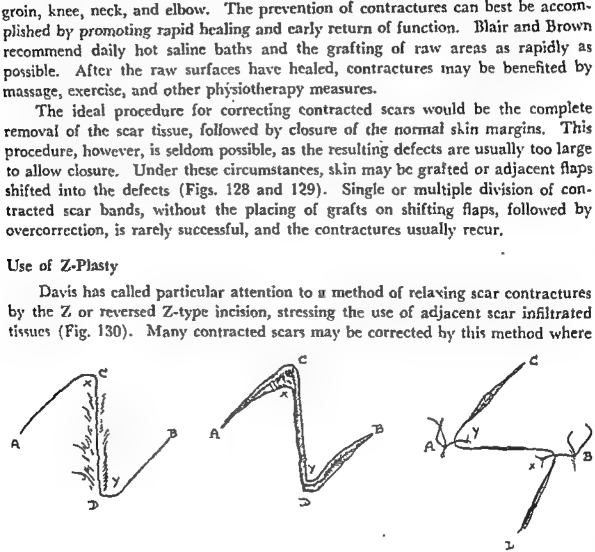

Fig. 130—Davis' Z-shaped incision for lengthening contracting band by utilizing adjacent flaps.

complete excision of the entire scar is impractical on account of its extent and location. Unless skin grafting is done or flaps shifted from a distant part, it is necessary to use scar or scar-infiltrated tissues, and often a great deal can be gained by the proper use of these tissues (Figs. 131-134). To utilize flaps of scar-infiltrated tissue, some procedure must be carried out which will relax the contracting band and break the line of tension. In certain cases this may be accomplished by the Z, reversed Z, staggered Z, S or reversed S incisions, or the procedure of F. S. Mathews (Figs. 135-137). The transposition of the flaps thus formed is made possible, because there is always shortening of the tissues in the direction of the contraction and usually excess of fullness on both sides and at right angles to the contracted band. Davis pointed out that the Z-type incision has been described in

many other articles and was used over ninety years ago. Recently it has been rediscovered and described as a *new procedure.* This method is most useful in relaxing or correcting the contractures which present a prominent bridle or web.

Fig. 131.

Fig. 132.

Fig. 131.—J B Extensive scar contractures of right axilla, elbow and body unsuccessfully treated elsewhere by grafts from parents.

Fig. 132.—J B, one and one-half months after correction of deformity shown in Fig 131 by multiple Z-shaped flaps transplanted at one operation

Technic.—Davis advocated marking the proposed incisions carefully with 5 per cent brilliant green in alcohol on the contracted area while the scar is under *tension. The longest line of the Z is placed along the most prominent portion of* the bridle or web. The arms of the Z are marked out on opposite sides of the central line forming angles of about 60°, with the central axis making the pattern a Z or reversed Z, depending on the condition of the adjacent tissues. The arms begin at each end of the central line on opposite sides and are carried outward and downward, and outward and upward, respectively, usually ending near the level of the center of the longest line. The incisions follow the pattern and extend *through the skin and scar tissue down to tissue with a good blood supply.* The two flaps thus formed are undermined, mobilized, and transposed. The tip of one flap is sutured into the angle at the outer end of the lateral incision forming the second flap, and vice versa Irregular points of the flaps are cut away and the

Fig 133.

Fig 134.

Fig 133—J. B. Posterior view of patient as shown in Fig 131.

Fig. 134—J B. Posterior view of patient as shown in Fig 132, one and one-half months after operation

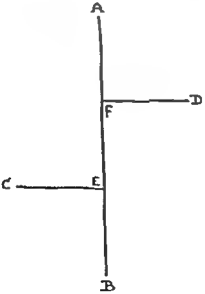

Fig 135—F. S Mathews' incisions for correcting narrow contracting bands. After incisions are made and the flaps undermined, *E* is sutured to *D* and *F* to *C*.

Fig. 136.—Narrow web scar contractures of right elbow, forearm, wrist, and thumb.

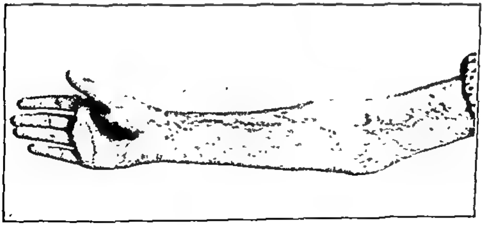

Fig 137.—Three months after correction of deformity shown in Fig 136 by multiple Mathews' incisions

wound is then closed with silk or cotton sutures. Multiple fine stab wounds may be made in the flap tips to relieve venous stasis and one or more small rubber tissue drains may be inserted beneath the flaps. Long sutures are passed through the drains and the free ends are brought out from beneath the margins of the dressings. This permits removal of the drains after forty-eight or seventy-two hours without disturbing the initial dressing. The wound is dressed with a single thickness of gauze impregnated with 3 per cent Xeroform ointment (petrolatum or Bettman's gauze) over which is placed a moist sea sponge or mechanic's waste applied under even pressure and fixed with adhesive plaster and an elastic bandage, and the part is immobilized.

In a grooved scar, the same procedure is followed. The long central incision of the Z splits the groove lengthwise and the flaps are formed just as when a bridle contraction band is present. Davis further pointed out that in many cases the flaps available are made up entirely of scar tissue and that only occasionally a bridle or web with even comparatively normal skin running up to the contracted band is found When the scar is thin and soft, it is split its full length into two sections, which are used as part of the flaps as described previously. When the scar contraction is thick and indurated, an elongated ellipse of tissue including the heavy scar is excised and the edges are brought together with a few temporary sutures to maintain the relationship of the parts. The Z or reversed Z is then outlined, the incisions are made, and the flaps undercut and transposed in the manner already described. This latter procedure presupposes that sufficiently relaxed tissue is present to permit excision of tissue as outlined.

Many modifications of the Z incision may be used, depending upon the shape and location of the scar and the line of greatest tension of the contractures. In planning this operation, care should be taken to utilize the best available tissue.

In dealing with wide scars, relaxation may be obtained at several points or in more than one direction by using multiple Z incisions. In long contractures, as from the axilla to the hand, two or more relaxation operations may be performed at one time (Figs. 136 and 137). Deep fibrous cords should either be divided or excised and all tension should be released before the flaps are sutured. As shown in the illustrations, the tips of the flaps should be made blunt, instead of pointed, to avoid sloughing. In spite of this precaution, the tips of the flaps do slough occasionally even though sufficient relaxation has already been obtained. Fortunately the defects left by the sloughs are usually small and heal rapidly, forming a smooth scar. In all flap operations it is best to have the flaps thick and to include some subcutaneous fat, if possible, to insure a good circulation. If the flaps become cyanotic after a few hours and this condition is not readily relieved by readjusting the dressing, changing the tension, and by secondary small stab wounds, it is advisable to apply continuous warm compresses of normal saline or saturated boric acid solution On theoretical grounds this may not appear wise, but in actual practice it is most helpful.

When the Z incisions are used on the fingers or wrist, the flaps should be short. Less constriction of the circumference will be produced by relaxing at two or more points In extensive contractures of long standing with atrophy and shortening of the deeper tissues, as much improvement as possible should be gained at the first operation with the Z-type incisions Six or more months later, after the deeper

tissues have stretched, the same procedure may be carried out in the same area The character of the scar usually improves to a surprising extent after the tension has been released.

We agree completely with Davis on the great usefulness and flexibility of the Z-type incision method. Further indications for its use are congenital shortening of the web bed between the thumb and index finger, short contractures about the nose, ears, eyelids, etc., and poor alignment of tissues, such as an injured eyebrow, the two parts of which have healed on different levels.

CLOSURE OF DECUBITUS ULCERS

The survival of many paraplegics following World War II has necessitated the closure of numerous decubitus ulcers in these patients. The ulcers are usually situated over bony prominences, as the ischial tuberosity or greater trochanter, and it is necessary to remove the underlying bony projections before permanent healing will result.

A B.

Fig 138—*A*. Delayed pedicle flap for sacral scarring which resulted from decubitus ulcer *B*, Final result sacral scar excised, flap transferred, and intermediate thickness skin graft applied to wound from which flap came

The surgical treatment of these ulcers usually entails the use of a pedicle flap, unless the defect is less than 2 cm. in diameter, superficial, and of recent origin. Before proceeding with construction of the flap the patient's general nutritional status as well as the local condition of the ulcer should be improved as much as possible. A long-standing ulcer with undermined margins will have a pseudo-bursal lining which must be excised. The wound is then packed daily to await the development of healthy granulations. Furacin ointment gauze is excellent for this purpose In the case of a sacral decubitus ulcer, the pedicle flap is outlined

with its long axis in a cephalad-caudad direction. The superior end of the flap will be situated in the loin, just below the twelfth rib. The inferior end usually overlies the gluteal muscles, lateral to the sacral lesion. Careful planning of the flap precedes the first stage operation. A safe rule is to make it no longer than two and one-half times its width. The width must be sufficient to allow excision of the ulcer, the adjacent scar, and about 1 cm. of normal surrounding tissue at the time of transfer of the flap.

Three operations are required for completion of the program at intervals of three weeks each. At the first operation incisions are made down to the deep fascia, creating the lateral margins of the flap. The intervening tissue is freed by sharp dissection in the fascial plane, thus creating a bridge attached above and below. The flap is then sutured back into place. Three weeks later an incision is carried down to the deep fascia, joining the inferior ends of the lateral incisions. This severs all vascular attachments of the flap except those which reach it from its cephalad end. These preliminary operations stimulate hypertrophy of the vessels which traverse the cephalad attachment, now termed the pedicle, and, it is believed, also accustom the flap to a lower oxygen tension and metabolic rate (Fig. 138, *A* and *B*).

Three weeks later the entire flap is dissected up, so that it is attached only by its pedicle. The circulation will usually be adequate to permit swinging its distal end to cover the defect resulting from excision of the ulcer. Before the latter is done, it is safer to wait from five to ten minutes in order to be certain of the circulation at the distal end of the flap. This can be done by noting the rapidity with which the cutaneous color returns following blanching from light digital pressure. If this is satisfactory, the ulcer with the adjacent scar is excised, any underlying prominence of bone is removed, and the distal end of the flap is swung into position and sutured into place. A split skin graft is sutured so as to cover the defect of the donor site. Graduated weight-bearing is started after four to six weeks.

For an ischial ulcer a similar flap from the upper posterior thigh is used. It is always desirable to resect the underlying ischium at the time the pedicle flap is transferred. If this bony prominence is removed, the pressure from sitting will be spread over a larger area and will not be localized to a narrow zone overlying the bone.

SYNDACTYLISM (WEBBED FINGERS)

Syndactylism is the most common congenital deformity of the hand. It involves the middle and ring finger most often, although any two or more fingers may be webbed. If there is evidence that the growth of the fingers is being altered, it will become necessary to operate in infancy, but surgery is most satisfactory when carried out in childhood. Dorsal and palmar triangular flaps are outlined at the base of each finger and after overcorrection of the depth of the web these flaps provide a noncontracting floor for the new web space (Figs. 139-141). The normal web is beveled to the dorsum. The defects resulting from separation of the fingers should be covered with split grafts. The obtaining of dorsal and palmar rectangular flaps from the web between the fingers should not be attempted, for sufficient tissue is rarely available and even when adequate skin is present for immediate

closure there is a strong likelihood that the web will recur and actual late deformity of the fingers may result.

In correcting webs secondary to burns the scarring will prevent the formation of triangular flaps, and tunnel grafts will be necessary. The grafting of the remainder of the fingers will depend upon the individual circumstances.

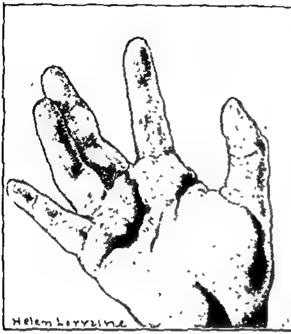

Fig 139.

Fig 140

Fig 139.—Incisions for operation for webbed fingers with palmar V-shaped flap outlined on middle finger.

Fig. 140.—Incisions for operation for webbed fingers with dorsal V-shaped flap outlined on ring finger.

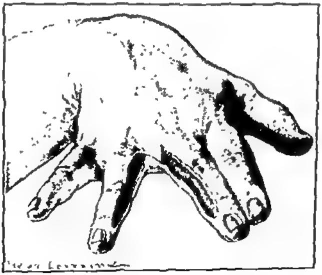

Fig 141.—Webbed fingers separated with palmar and dorsal V-shaped flaps shown in Figs 139 and 140 and brought across the base of the interdigital space The raw areas should be covered with free skin grafts

KELOIDS

An early keloid is a connective tissue overgrowth Later on, it is composed largely of broad bundles of dense connective fibers with intervening cellular-shaped elements . Hypertrophied scars and true keloids are considered by many as separate

conditions, but others think them different stages of the same process. In a true keloid the sebaceous glands and hair are supposed to be retained, but this is not true in hypertrophied scars. They may develop in certain susceptible persons, especially in young Negroes, following slight trauma or from a perfectly healthy scar (Fig. 142). They reach the greatest size where the healing has been slow and

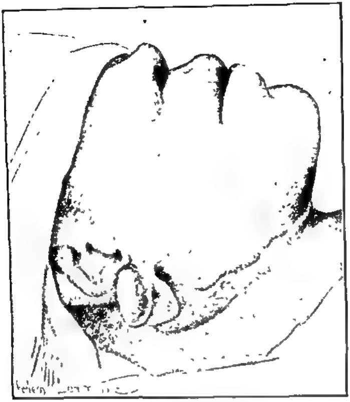

Fig. 142—Rapidly growing keloids following perforation of right ear lobe for rings. The left ear had similar keloids.

Fig. 143—Results obtained in case shown in Fig. 142 twenty-six months after treatment of right ear by preoperative and postoperative radiation and surgical excision. No recurrence. The left ear responded to the same treatment.

infection has been present, as following extensive burns. There is no known way of foretelling the development of a keloid or of preventing its appearance. Keloids give trouble not only by causing deformity in appearance, but also by interfering with function. They frequently are painful and produce persistent itching and burning. The treatment of this condition has been unsatisfactory. Simple excision

closure there is a strong likelihood that the web will recur and actual late deformity of the fingers may result.

In correcting webs secondary to burns the scarring will prevent the formation of triangular flaps, and tunnel grafts will be necessary. The grafting of the remainder of the fingers will depend upon the individual circumstances.

Fig. 139

Fig. 140.

Fig. 139.—Incisions for operation for webbed fingers with palmar V-shaped flap outlined on middle finger.

Fig 140.—Incisions for operation for webbed fingers with dorsal V-shaped flap outlined on ring finger.

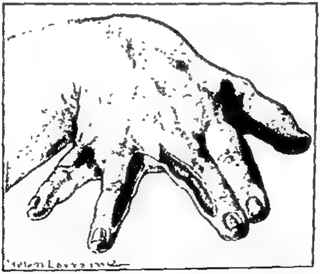

Fig 141.—Webbed fingers separated with palmar and dorsal V-shaped flaps shown in Figs 139 and 140 and brought across the base of the interdigital space. The raw areas should be covered with free skin grafts

KELOIDS

An early keloid is a connective tissue overgrowth. Later on, it is composed largely of broad bundles of dense connective fibers with intervening cellular-shaped elements . Hypertrophied scars and true keloids are considered by many as separate

CHAPTER 16

TRANSPLANTATION OF FLAPS CONTAINING SKIN

HUNTER S. JACKSON

A free graft is a piece of tissue completely detached from its original position (donor area) and transplanted in one sitting to fill in or cover a defect in an adjacent or distant part of the body (recipient area).

A flap, or pedicle graft, is comprised of a portion of skin with its vascular system and attached subcutaneous fat which remains connected to its donor area by a portion of its periphery, while another portion of its periphery is transferred into the recipient area. The attachment to the donor area is termed the pedicle, through which arterial and venous circulation nourishes the flap until a satisfactory blood supply is established between the recipient area and the adjacent portion of the flap.

A free skin graft consists of a varying portion of the thickness of the skin, without subcutaneous elements. It is completely detached from the donor area and transferred wherever desired, viability being maintained for the first twenty-four to forty-eight hours by osmotic interchange with the intercellular fluids of the recipient area Skin grafts are usually divided into two general types, thin grafts and thick grafts. In the thin graft group are placed the small Reverdin ("pinch") grafts, the Ollier-Thiersch grafts, and seed or implantation grafts. In the thick graft group belong the small deep grafts of Davis, the thick split grafts of Blair and Brown, the full thickness skin grafts of Wolfe-Krause, the tunnel graft of Keller, and the sieve graft of Douglas.

An autograft is one obtained from the patient himself; a homograft is one obtained from another individual of the same species. A zoograft is from a member of another species. Autografts should practically always be used, since the permanency of a homograft is exceedingly rare. It may be desirable, rarely, to use skin homografts in the critically burned patient as a lifesaving measure to prevent profound protein depletion Such grafts may survive ten days to two weeks before sloughing, by which time the patient's general condition will permit autografting. Zoografts have no place in plastic surgery.

SOURCES OF GRAFTS

Skin grafts may be taken from almost any portion of the skin surface. The source of the graft has little effect on its success or failure, but certain considerations must be kept in mind. Generally, a thin graft will take more readily than a thick graft This is of importance where the graft is to be used on a granulating surface or within the oral cavity On the other hand, the cosmetic appearance of a thick graft is better, and the likelihood of contracture and wrinkling is less than

of a keloid will usually be followed promptly by a recurrence even more extensive than the original lesion. The most satisfactory method of treatment is the combination of surgical removal and skillful radiation therapy (Fig. 143). Hodges believes that thick, localized, old keloids should be removed surgically and post-operative irradiation given. This treatment should be begun immediately after operation. Radium and roentgen radiation are equally efficacious, but when large areas are involved, the roentgen ray is more practical.

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DRESSING OF DONOR SITE

There are many methods of dressing the donor site of the various skin grafts. In general, fine mesh gauze, either plain or impregnated with petrolatum, Xeroform, scarlet red, or Furacin ointment, should be applied, followed by additional gauze pads to effect a firm dressing. It usually is not necessary to apply a true pressure dressing or to immobilize adjacent joints. It is desirable to leave the dressing alone for ten to fourteen days, by which time the donor site for many of the grafts, such as split skin grafts, small deep grafts, and Ollier-Thiersch grafts, will be healed. Excessive soilage of the dressings during the interval may necessitate changing the outer dressing down to the fine mesh gauze. Any subsequent dressings will depend upon the appearance of the wound at that stage of healing.

FLAPS

Flaps may be divided into sliding flaps and pedicle flaps. A sliding flap (French method) is sutured into the wound from the immediate locality after making the incisions in various directions from the original defect and undermining the wound margins. The use of sliding flaps is limited chiefly to defects of a minor degree about the face. When they are used in this locality for larger areas, undue distortion of normal tissues is likely to result. The principle of the sliding skin flap is also employed in the correction of a scar with a moderate amount of depression. The scar is first excised and the skin margins are undermined; the subcutaneous fat on each side is partially freed so that it can be sutured into the center of the wound, obliterating the depression; the skin is then sutured over the filled defect.

Pedicle flaps may be divided into three general types: simple, compound, and lined flaps The simple pedicle flap is composed of full thickness skin and a varying amount of subcutaneous tissue. The compound pedicle is made up of full thickness subcutaneous tissue with the addition of bone, cartilage, or muscle. In a compound flap containing bone, the periosteum is included with the bone, without separating it from its normal position. An example of such a compound flap is one taken from the clavicle to fill a defect of the jaw (Figs. 144-146). When muscle is transplanted, as in the closure of a large thoracic wound, the muscle is left attached to the skin and subcutaneous tissue with its normal blood supply. Cartilage, forming a part of a compound flap, is easily implanted into the flap as a free graft, since the cartilage is usually taken from the costal region. When the defect, which has been lined with mucous membrane or skin, is to be repaired by a pedicle flap, it is necessary to line the flap with epithelium before it is transplanted. Unless this is done, the flap will contract or be lost entirely. The flap may be lined by several different methods: the raised flap may be folded, or two flaps may be raised and their raw surface allowed to grow together, and then the flaps may be transplanted. The simplest way to line a flap is to place accurately a split skin graft or full thickness graft under that portion of the flap which is to be lined, adjusting the raw surface of the graft to the underportion of the flap. The pedicle flap is then sutured back into its bed and even pressure is applied with foam rubber or sea sponge. After ten days to three weeks, the flap is raised and transplanted to its new position. Careful selection must be given the type and texture of skin which is to line the flap. Hair-bearing skin should not be used where the lining is to replace mucous membrane, such as within the mouth. A pedicle flap to restore an eyelid should be

that of a thin graft. Due regard should be had for the requirements of the recipient area, as to color, texture, size, and presence or absence of hair. Where the facial defect is small, particularly about the eyelids, it is best to obtain the graft from a redundant eyelid, the postauricular region, or the supraclavicular region. When hair-bearing skin is required, it can be obtained from the mons pubis and axilla. Some care is desirable in the selection of the source of the skin graft so that the resulting scar will be as inconspicuous as possible. In obtaining large full thickness skin grafts for the face or neck, skin from the inner side of the arm or lateral portions of the chest is satisfactory. The anterior and lateral surfaces of the thigh and the abdomen are the best sources for a split thickness graft.

PREPARATION OF SOURCE OF GRAFT

The surface from which the graft is to be taken may be prepared by any of the methods suggested in the discussion of skin preparation. It is inadvisable to use very strong antiseptics unless they are removed before the graft is obtained.

Since 1944, considerable attention has been directed toward the use of soaps containing G-11, or hexachlorophene. Studies on its bacteriostatic efficacy would seem to make it the agent of choice both for the surgical scrub and the preoperative skin preparation. An afterrinse should not be used, since it deactivates hexachlorophene.

If the area to be grafted is not a raw surface, the cleanup is the same as the usual donor area preparation. If the area to be grafted presents any unhealed granulations, there are several methods of preparing such a surface. Open methods, such as frequent saline tubbings with interval wet compresses, may be the method of choice in extensive wounds of the trunk, especially of the buttocks and genitalia. Moist compresses are also the treatment of choice for granulating wounds of the face and hands. If it is advisable to administer antibiotics, they should be given parenterally, although local use has been advised by some authors. When the active infection has subsided and the granulations are bright red and healthy, only normal saline dressings should be used for at least forty-eight hours prior to operation. As mentioned, a full thickness skin graft does not take well even on a healthy granulating surface. If, because of its better cosmetic appearance or greater stability, it is desirable to use such a graft, a closed, healed wound should first be obtained by applying a split skin graft. At the time of operation for application of the split skin graft, it is best to shave off the granulations with a razor or a skin graft knife down to the yellowish base of the granulating bed. Bleeding from the wound is controlled by hot saline compresses, applied under manual pressure by an assistant while the skin graft is being obtained. In certain instances of old granulating wounds with considerable subjacent avascular fibrosis, it is advisable to do a somewhat more radical dissection of the granulating area down to a more normal tissue level so that the blood supply will be adequate to support the graft.

A graft transferred to denuded bone, as on the skull, may not survive if the bare area exceeds a few millimeters in diameter. If a larger area is exposed, the wound should be prepared a few weeks in advance by carefully drilling a series of holes at close intervals through the outer table of the skull. From these holes will appear granulations, upon which the graft may be placed. This more vascular bed will then be adequate for survival of the graft.

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lined with mucous membrane, as even the thinner split grafts may contain hair and cause too much irritation for a satisfactory result.

Pedicle flaps are further classified as open or tubed, depending on whether the undersurface of the pedicle is an open, raw, granulating surface or whether its lateral margins have been sutured together in the form of a tube. Each has its indications and advantages. The transplantation of a pedicle flap may be immediate, being dissected up and transplanted at one operation, or it may be delayed in order to assure proper circulation. In the delayed transplantation, varying inter-

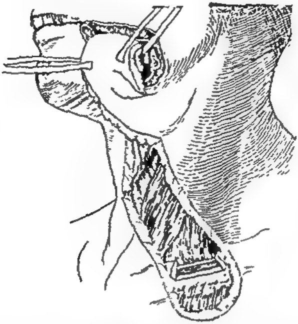

Fig. 144.—Reconstruction of defect in the lower jaw by a pedicle flap including a portion of the clavicle. The flap is long enough to reach over the section of clavicle into the mouth and completely envelops the bone.

Fig. 145.

Fig. 146.

Fig 145.—Lines of incision for repair of defect in the midline of lower jaw. A piece of rib has been previously grafted under the skin of the flap.

Fig 146.—The flap with its grafted bone is turned into the defect of the lower jaw. The skin is long enough to fold over the grafted bone

A.

B.

C.

Fig. 147—*A*, Abdominal tubed pedicle flap to cover old burn defect on inner surface of left ankle *B*, Flap migrated to defect via intermediary wrist attachment. *C*, Flap severed; final smoothing out not yet done.

vals of time are allowed between the dissecting of the flap and its removal to its new bed. This delayed transfer may require multiple stages in order to develop the circulation. Flaps may be transplanted by successive migration stages from distant parts of the body. (Fig. 147.)

SOURCES AND GENERAL PRINCIPLES

The chest and abdomen afford the largest areas of skin on the body from which to obtain pedicle flaps. These flaps are usually tubed and can be used to fill large defects of the face, neck, axilla, and upper extremities. Other principal sources of pedicle flaps are: the anterior and lateral surfaces of the arm, a good

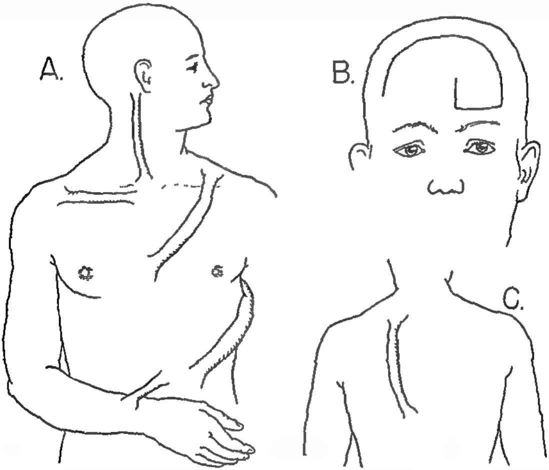

Fig 148.—*A*, Anterior donor areas most often used for tubed pedicle flaps. *B*, Open forehead flap *C*, Posterior donor area for tubed pedicle flap

source for a tube flap for large defects of the face, the back, for tube flaps for large defects of the face, neck, and axilla; the neck, for small defects of the cheek, lip, and external ear (Fig. 148) The disadvantage in this cervical source is the formation of additional scars in a conspicuous area. This is particularly true in a female patient The scalp is the best source for hair-bearing skin transplants and may even be used for a double pedicle flap for defects of the chin and lips in the male The forehead is an excellent source for rhinoplasty and for covering small or medium-sized defects of the upper half of the face. The skin of the lower back may be used for defects of the hand and forearm, while the lower thigh and calf may furnish flaps for repairing defects of the lower extremities and are particularly suitable for covering the sole of the foot (so-called crossed leg flaps) (Fig. 149)

Often incisions may be made or flaps may be so shaped as to secure tissue from the neighborhood, which at first might seem impossible. Due regard must always be had for nutrition of flaps, and the pedicle should be located preferably in the general direction of the blood supply of the skin from which the pedicle is formed. The flaps should be handled as little and as gently as possible. It must be borne in mind that unnecessary trauma not only destroys living tissue in a flap, but adds an extra burden to the blood supply which must absorb the injured cells and bring nutrition for the repair of the defect. To this end, sharp skin hooks, mosquito hemostats, and small thumb forceps do much to minimize tissue damage. In very vascular regions, such as the face and scalp, it is often possible to disregard the direction of the blood supply in making a flap because it is so abundant and the collateral circulation is so great that a flap may be sufficiently nourished if the pedicle is large enough, even though the blood must come from the opposite direction of the normal supply.

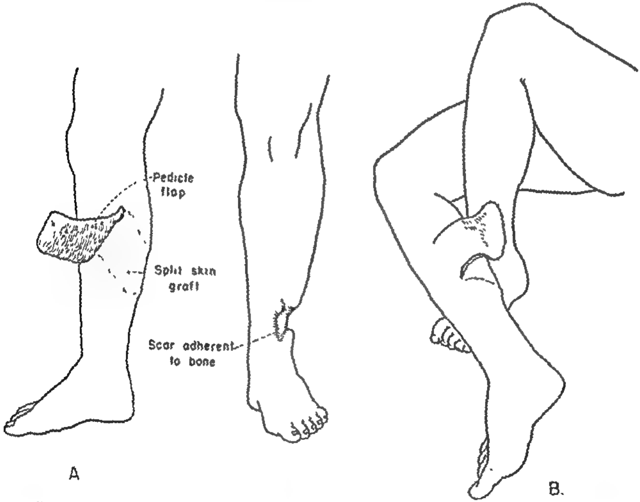

Fig 149—*A*, Flap elevated on donor leg, showing skin graft applied to cover flap bed. Defect in opposite leg. *B*, Flap in place after excision of scar.

Besides handling the flap gently and providing sufficient nutrition through its pedicle, care must be taken to insert the sutures so as to avoid too much tension. No matter how carefully the pedicle may be handled or shaped, if it is sutured so that there is too great tension or torsion, the blood supply will be obstructed and the flap will be partially or totally destroyed. Occasionally when tension in a flap is unavoidable, it is best to concentrate it upon one or two tension sutures that will

produce pressure only in one or two areas and relax the rest of the flap so there will be enough nutrition along the margins for satisfactory union. The nutrition of a flap may be imperiled also by venous stasis. McIndoe and C. H. Mayo emphasized this point. Not infrequently the blood supply to a flap would be sufficient except that the venous return is imperfect and blocks the capillaries, which in turn prevent the feeble arterial current from being effective. Wherever a large flap with a narrow pedicle is transplanted, this condition may result and should be carefully avoided by making several short stab wounds in the substance of the flap and by leaving small gaps between the stitches along its margins through which the venous blood may escape, thus relieving the passive hyperemia.

If the flap cannot be carried to the affected part, as is done in defects about the face, the affected part can sometimes be carried to the flap, as in plastic operations on the hands or on the lower extremities. Defects about the hand, forearm, or the elbow may be repaired by a flap from the abdomen, which is dissected up as a bridge of tissue between two parallel incisions and is left attached at each end. The defect on the hand is prepared for a graft and the hand is inserted under the bridge, and the edges of the skin of the bridge of tissue are sutured to the margins of the wound of the hand. After about two weeks the flap is gradually cut away. By making a flap with its broad base from the upper part of the abdomen, the whole portion of the flap except its base can be sutured to the defect. In this way lesions of the palm of the hand are satisfactorily repaired and the patient is much more comfortable than when the hand is carried to the back. By this latter method virtually a closed wound is obtained, without the attendant increase in fibrosis that an open granulating flap would entail. Shaw and Payne utilized a one-stage tubed flap, pedicled on the inferior epigastric artery, for small defects about the fingers and hand, elevated, tubed, and attached to the recipient area in one sitting.

It is always necessary to see that the flap is sufficiently nourished by its new location before the pedicle is divided. When the pedicle is first severed the flap always becomes pale but if the patient is young and relatively healthy and the flap is in good condition, a pedicle can usually be cut safely at the end of two to three weeks. If in doubt, it is advisable to compress the pedicle with a soft-bladed clamp or an elastic band for an hour or more daily for several days before severing it. In this way collateral circulation is developed. At times it is desirable to sever one-half of the pedicle and, after seven to ten days, to divide the remaining tissue.

Hynes' atropine absorption test is a simple and apparently accurate means of estimating the blood supply in flaps and tubed pedicles. It is primarily a qualitative test, which is dependent on the absorption of atropine in sufficient quantity within thirty to forty-five minutes to produce two of three easily detected symptoms and signs: About twelve to fourteen days after transfer of the flap or pedicle into the recipient area, a soft-bladed clamp is applied in such a manner as to compress the circulation of the long axis of the flap. Atropine sulfate, 1/75 grain, is injected subcutaneously into the recipient end of the flap or pedicle. Blurring of vision, dryness of the mouth, and increased pulse rate, with the time of their appearance, are noted. The presence of two of these within thirty to forty-five minutes indicates adequacy of circulation between the transferred end of the flap and the recipient area, and the pedicle may then be severed.

If it is desired to transfer a long narrow flap from the neck to a region on the face, it is too hazardous to imperil the nutrition by doing the operation in one stage.

The circulation of the flap, however, can be developed by first outlining the flap by incisions, then the bridge of tissue for the pedicle is undermined, and the incisions are sutured. In this manner the nutrition at the ends of the flap will be increased. After ten to fourteen days the end that is to be severed is divided in sections at intervals of three to five days so that all of the nutrition will be gradually developed from the pedicle.

Blair, in 1921, published certain conclusions which are still essential in making and transplanting successfully skin flaps for the correction of defects. In the region of the neck and face of a man, rather long flaps can be made with little danger to their vitality, provided the return circulation is not retarded by gravity and not obstructed by kinking or torsion of the pedicle. In women and children, the circulation of the face and neck is not so vigorous, and equally long flaps are less likely to survive. If a flap sloughs in its original position, the portion lost will be considerably less than if it had been transplanted immediately. The slough of an untransplanted flap is likely to be superficial without necrosis of the full thickness of the skin, yet a slough occurring after transplantation is more apt to involve the entire thickness of the flap. If a recently transplanted flap shows evidence of sloughing, it is safer to replace it in its original wound. By so doing, time will be saved and usually a smaller part of the flap will be lost. If a flap is to be split into two or more narrow flaps to cover defects, such as those of the eyelids and lips, the splitting should be delayed until the time of transplantation. If any part of a flap sloughs in its original bed, that area, regardless of how superficial the slough may be, should not be transplanted.

There are other fundamental principles about the technic of cutting and transplanting flaps. In order to allow for shrinkage the usual flap should be made somewhat larger (usually one-third) than the defect it is to fill. It should correspond fairly accurately in shape, though flaps made from normal tissue are pliable and can easily be adjusted to fit a wound of almost any shape. Long, pointed, and sharp-cornered flaps should be avoided, as the circulation in the tips is often inadequate, and a slough will result. The subcutaneous fat should be slightly thicker than the immediate need in order to allow for shrinkage. When the flaps are obtained from the forehead, where there is little if any subcutaneous fat, the size and shape of the flap must be cut very accurately. Accuracy is especially important in rhinoplastic operations. A pedicle flap should be as broad as possible, but where the tissue must be twisted, the pedicle should be narrower than the main body of the flap. The length of a pedicle flap for immediate transplantation should not be more than two and one-half to three times its width unless the pedicle contains a main artery and vein. A main artery is not essential if the pedicle is sufficiently wide, and it is usually better to have the flap thick enough to contain a number of small vessels for its nourishment. The length of a single pedicle flap with delayed transfer should not be over three to three and one-half times its width.

TUBED PEDICLE FLAPS

One of the most interesting and valuable procedures in plastic surgery is the development of the blood supply from a comparatively small pedicle. In extensive reconstruction work about the face this procedure is essential for success. "Tubing" of the pedicle, of such a size and shape as may be best suited to the facial defect.

was first described and demonstrated in 1916 by Filatow of Odessa. Gillies of London made an independent but similar report in 1917 and subsequently popularized this method. The tubed pedicle is prepared by making two parallel incisions through the skin and subcutaneous tissues in the selected donor site (*Fig. 148*). After dissecting the pedicle from its base to the margins of the proposed flap, the edges of the skin of the pedicle are brought together with a few interrupted and continuous sutures of silk or cotton. In this way the raw surface of the pedicle is protected from infection and also from the trauma and loss of blood to which an exposed granulating surface is subjected. The margins of the wound from which the pedicle has been dissected are undermined and united beneath the tubed pedicle so there is a minimum of raw surface exposed (Fig. 150). If necessary, because of undue tension, the wound may be surfaced with a split thickness skin graft. Ten to fourteen days later one-third of the flap is dissected from its bed.

Fig 150—Gillies' four-point suture for apposing raw triangular ends in formation of a tubed pedicle flap.

If the flap is to cover part of the cavity of the mouth, its raw surface is grafted with thick split skin grafts, or two flaps may be developed with tubed pedicles and one turned with the epithelial surface within the mouth and the other with the skin external. At intervals of about one week the flap is again dissected in three stages, covering a period of three to six weeks, until it is entirely free except for the pedicle. This procedure will develop a blood supply through the pedicle so that the flap may be transferred without fear of insufficient nutrition. Sometimes, as recommended by Gillies, a large flap to cover an extensive defect of the face can be raised from the front and upper part of the chest by having two tubed pedicles, one on each side of the neck. When the pedicle is severed after the flap is in place, it may be cut gradually, severing about one-third at a time, at intervals of one week, or it may be compressed with a soft-bladed clamp or a rubber band for an hour or more daily for several days before it is severed. In this way the blood supply is gradually thrown upon the new attachments of the flap in such a manner that the local nutrition is surely established, whereas a complete severing of the pedicle without preliminary preparation might result in such poor nutrition that the flap would slough.

When the pedicle or the lateral skin attachments of a tubed flap are divided, local anesthesia may be used. It should not be injected into the flap, however, but into the tissues adjacent to it. Injection of the anesthesia into the flap itself may interfere seriously with the circulation. Where gradual division and undercutting are done, it is necessary to dissect off the thin layer of scar tissue and remove all granulating tissue before shifting the flap into the defect. When the tubed portion is to be used or when the unused portion of the tube is to be replaced in its original bed, the superficial scar where the skin margins were brought together, along with the deeper scar leading to the central portion of the tube, should be excised before the tube is opened. If the tube portion of the flap is used in the reconstruction, allowance must be made for the shrinkage of the tissue constituting the tube. When a wide section of skin is required, the double pedicle flap sutured back into its bed without tubing the pedicles should be chosen, because of less shrinkage.

Fig 151.—Tubed pedicle flap extending from abdomen to lumbar area with an intervening "bridge" attachment.

The unrolling or opening of the tube is an important step. All incisions in the subcutaneous fat of the tube must be made longitudinally and as few incisions should be used as necessary to allow satisfactory opening of the tube in order to avoid damage to the blood vessels of the flap. After the unrolled tube is sutured into its new position, the pedicle end of the tube must be carefully placed so that there is no kinking either from gravity or from its new position. Three to four weeks or longer must elapse to permit healing of the flap in its new bed. The pedicle is then transferred to its new position, removed, or sutured back into its original bed, as may be indicated

Very long tubed flaps may be made with success by the delayed transfer method. A procedure reported by Webster makes even longer tubed flaps possible. His method (thoraco-epigastric flaps) is to raise and tube the flap in two or more sections, with an interval of untouched skin between each tube (Fig. 151). This assures the blood supply during the early stages when it is usually unstable. After a brief period of time, these untouched areas of skin are successively dissected, the tube is completed, and later the tubed flap is transferred. At the original operation it is advisable to mark by short stab wounds in the skin the exact location of the incisions which are to complete the tube later on. The small scars made by these stab wounds will act later as a guide for the incisions. At the time of the second operation it is important to carry the dissection well down to the fascia.

MIGRATING PEDICLE FLAPS

Tubed flaps may be migrated by "waltzing," by "caterpillaring," or by using an intermediary such as the arm or leg. When a flap cannot be placed directly upon the recipient wound, a tubed pedicle flap should be used. "Caterpillaring" or

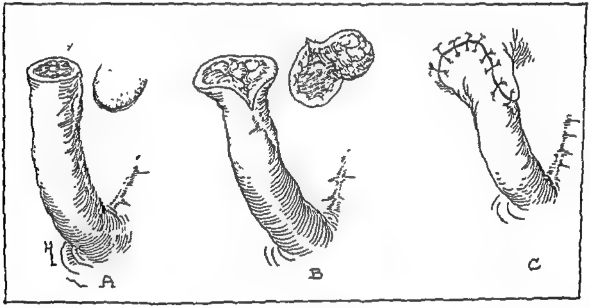

Fig. 152.—*A*, Trap-door flap Stippled area is the imprint of end of tubed pedicle on the wrist, which is incised and undermined. *B*, Trap-door flap reflected and prepared end of tubed pedicle *C*, Tubed pedicle and trap-door wrist flap sutured. When migration is completed, the trap-door flap is returned to its original bed.

advancing a tubed flap in the direction of its axis is sometimes useful when it is desirable to transplant a flap from an adjacent area and when torsion on the tube must be avoided A flap may be turned, for instance, to the margins of the wound and kept there until the nutrition is well established. Then its pedicle is cut and turned over the defect. A flap from the abdomen may be sutured into a trap-door wound made on the wrist for its reception and migrated via this intermediary (Figs. 147 and 152). After it has taken, the pedicle to the abdomen is cut and the wrist with the transplanted flap is carried to the face or other area. The flap is sutured into its new position, the pedicle to the wrist is severed at the proper time, and the trap-door flap on the wrist is restored to its original condition

CROSSED LEG FLAPS

The crossed leg flap is an open flap used in repair of surface defects of the lower extremities, in which the opposite leg serves as the donor area for the defective leg. The general principles of such a flap differ little from flaps on other areas of the body. Careful planning as to size, direction of blood flow, proper position to avoid tension or torsion, and immobilization during the time of transfer are imperative for success.

Indications for the use of a crossed leg flap are unstable or painful cicatrices attached to bone, scarring or surgical defects over the weight-bearing portions of the foot, and extensive scarring over the Achilles tendon.

Usually two preliminary steps two to three weeks apart are necessary to insure adequate circulation prior to transfer of the flap into the defect. When the flap is initally constructed at the first operation, a split skin graft is applied beneath it to cover the bed from which it came. The transfer may usually be done two weeks after the second delaying operation. The day before transfer, it is wise to apply plaster casts to both legs which will produce the desired positions, permitting transfer of the flap and at the same time immobilization of the extremities. This will enable the surgeon to evaluate the comfort of the casts, the status of the peripheral circulation, and will also permit setting of the plaster. This will avoid the possible production of tension on the flap due to mishap during the setting of casts applied immediately after transfer of the flap. If the casts are deemed unsatisfactory, they may be replaced, waiting another twenty-four hours before operation to recheck these factors. Adequate windows are cut out of the casts over the flap and the recipient area. At the completion of surgery cross-bracing is applied to join solidly the two casts without tension or torsion on the pedicle.

Usually three weeks must elapse before the pedicle may be cut half across. In this manner, as mentioned earlier, sufficient collateral circulation from the recipient area is developed before severance, which may be carried out a week later. The casts are removed, and the severed edges of the pedicle are appropriately trimmed and sutured in place on their respective legs. In the case of a flap applied to the sole of the foot, weight-bearing is carefully begun four to six weeks after the last procedure During this interval, physiotherapy is indicated to mobilize the joints of both legs which will have stiffened while in the casts.

Contraindications to the use of a crossed leg flap are: undesirable scarring on the donor leg in a female patient, advanced age of the patient which might result in permanent joint damage due to the immobilization, and preexisting arthropathies.

DOUBLE PEDICLE FLAPS

A double pedicle flap is made by raising a flap attached by a pedicle at each end and sliding it to the defect. Such a flap from the submental and upper cervical regions is useful in restoring the lower lip and chin. A flap can also be made from the scalp with its attachments in the temple on each side and brought down to restore the lower lip and chin in the male. This method is particularly suitable for large defects in the region of the midline of the face. A similar flap, termed a "visor" flap, has been used by Straith and Beers in traumatic avulsions of the anterior scalp to restore the forehead hairline, using a double pedicle flap which brings forward hair-bearing occipital skin.

On occasion a double pedicle sliding flap may be useful on an extremity where there is a long narrow scar attached to bone. After the flap is slid over to close the defect, the counter defect is covered with a split skin graft.

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CHAPTER 17

FREE GRAFTS OF SKIN AND MUCOUS MEMBRANE

LEROY SMITH

The transplantation of skin and mucous membrane has been in practice for centuries. However, it was not until Reverdin in 1872 published his work under the title of *Epidermic Grafts* that interest was aroused in this procedure. Other surgeons, namely, Oliver, Thiersch, Krause, and Wolfe followed in rapid succession with reports of their experiences with various types of skin transplants. The indications for the transplantation of skin are numerous, but mainly where skin has been destroyed or damaged following trauma and disease. The transplantation is not a success unless the skin lives and serves functionally and cosmetically the purpose for which it was applied. Improvements in recent years have contributed notably to our understanding of the best methods to be used to attain this end. Most skin that is transplanted is autograft, that is, the patient's own skin is used for transplantation. Experimentally, homografts—skin taken from one individual and placed upon another of the same species—have been tried, but so far successful "takes" have not been permanent.

There are multiple classifications of the free grafts (Fig. 153) of skin and mucous membrane, but one of the simplest is as follows:

1. Split thickness grafts
   a. Epidermal grafts
   b. Small split grafts
   c. Intermediate grafts
   d. Dermal grafts
2. Full thickness grafts
   a. Large full thickness grafts
   b. Small full thickness grafts
   c. Sieve grafts
3. Tunnel grafts
   a. Split thickness
   b. Full thickness
4. Composite grafts

PHYSIOLOGIC PROPERTIES OF GRAFTS

When one transfers a free piece of skin and applies it to a raw surface and maintains this contact by immobilization, immediate healing begins. The recipient site begins to throw out an exudate which contains fibrin. This fibrin forms a network which attaches itself to the undersurface of the graft. Into this fibrin network go leukocytes and fibroblasts followed by a relatively rapid formation of small capillary buds which at the end of three days can be seen extending into the lower layers of the graft. By the end of the seventh day, there is a fairly firm union between the two surfaces. For the first twenty-four hours the skin receives its nourishment through the plasma in the exudate. After the third day, the nourishment

is almost wholly taken over by a circulation of blood through the capillary bed From the time the graft is applied to the end of the first week, the development of infection, hemorrhage, or motility will disturb the normal healing process and a successful "take" will be jeopardized. It is within this period that all grafts should receive the utmost care and protection. If one suspects that either of the above complications has arisen prior to the seventh day, measures should be taken to correct

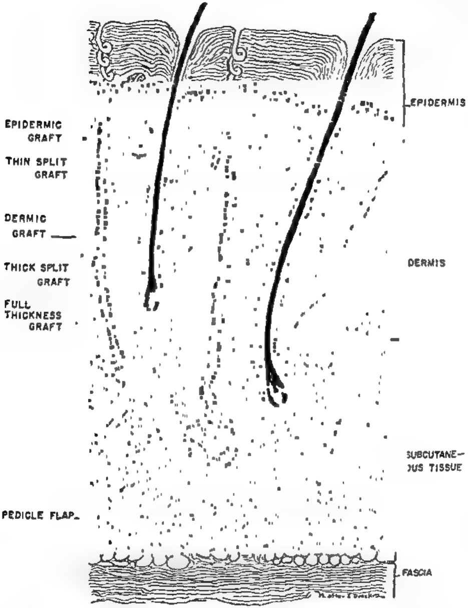

Fig 153.—Section of skin showing the different cellular layers. Approximate layers included in the various grafts are described on the left side of the figure.

it. Otherwise, the graft should not be dressed or disturbed. The symptoms suggesting danger are. (1) elevation of temperature, (2) excessive swelling, (3) discoloration around the graft site, (4) pain, and (5) shifting of the bandages overlying the graft. If early attention is paid to these signs and symptoms, and measures are taken to correct them, one may avert total failure The size, thickness, and location of the grafted skin have a definite influence on its physiologic pattern of behavior. It is known that full thickness or thick split thickness grafts will not take

where there is evidence of infection on the recipient area, where careful hemostasis of the grafted area has not been complete, and where the slightest shifting of the graft has taken place. Even as late as the fifth day these complications may end in failure of the graft to grow.

Thick grafts frequently change color when transferred to a new environment, becoming highly pigmented, particularly when placed on exposed surfaces. However, they do have distinct advantages in that contraction is very slight following healing and the resistance to trauma is excellent and they retain their elasticity, approaching that of normal skin. If these grafts contain hair follicles, one may expect a continuation of growth of hair following transplantation. The resistance to local infection following healing is the same as that of the surrounding skin. In thin split thickness and epidermal grafts one may expect successful "takes" on sites that are covered with granulation tissue. These grafts do not require the high degree of immobilization that we find with the thicker skin transplants. For this reason they can be used as epithelial dressings where infection is present and where one cannot obtain fixation for a long period of time. Their main disadvantages are that contraction, which frequently may be as much as 50 per cent of the total area, may develop and their resistance to trauma is extremely low. The elasticity of thin grafts is less than that of normal skin and, consequently, their application over joint surfaces should be avoided.

SPLIT THICKNESS GRAFTS

Split thickness grafts may be divided into four classifications, namely, epidermal grafts, small split grafts, intermediate grafts, and dermal grafts.

The epidermal graft, or the so-called "isle of Thiersch," is taken from the outer layer of the skin including the epidermal layer and the tips of the papillae. It is preferable to select as a donor site that portion of the skin surface which has no or a relatively small amount of hair, such as the flank or the inner surface of the arm and thigh. Its application can be made on fresh or raw wounds or on healthy granulating wounds. Occasionally, it may be used on infected granulating tissue as an epidermal covering. This choice is made, however, only in the case of an emergency.

Technic for Removing Split Thickness Grafts

The donor site is first prepared by scrubbing the skin surface with soap and water the night before and covering it was a sterile towel, which is left in place until the graft is ready to be taken. The towel is then removed and the area is painted with 70 per cent alcohol which is allowed to dry. The method of obtaining epidermal grafts is the same as that applied to any type of split thickness of skin. One may use a freehand razor-sharp knife, having the assistant maintain traction on the skin by holding two boards, one at each end of the area to be removed, flattening this area and putting it under moderate tension. The knife is then used to shave off the outermost layers of the skin in the desired width and length (Figs. 154 and 155). To facilitate this, the Blair suction box may be used (Fig 156) with which the operator can maintain a more even amount of traction.

The most satisfactory method is to remove these grafts by the use of a dermatome, such as the one devised by Padgett. This dermatome consists of a drum over

which a blade revolves. The blade can be set at various distances from the drum, giving a uniform thickness to the graft. The technic is as follows: The drum is cleansed first with alcohol and then with ether to assure absolute freedom from moisture.

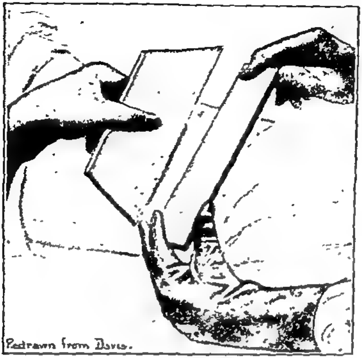

Fig. 154.—Two boards used to keep the skin tense while taking a graft.

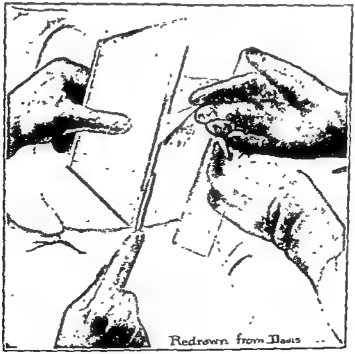

Fig. 155.—Graft is cut with a long amputating knife while the wooden boards keep the skin tense.

The drum is covered with an adhesive which is made for this purpose. Following cleansing of the donor site, the glue is distributed over the area corresponding to that of the drum (10 to 20 cm.). The surfaces of the drum and skin are allowed to dry thoroughly and the knife is adjusted to the desired thickness by the gauge

on each side of the drum. The drum is placed on the surface with the two adhesives in contact and rotated slowly upward, pushing the knife backward and forward across the elevated portion of skin. This allows the skin to remain adherent to the surface of the drum until complete removal of the graft. The skin is then removed from the drum and all of the adhesive is removed from the skin before it is placed upon the recipient site (Figs. 157 and 158). There is also an electric dermatome which cuts the skin by using a vibrating blade guarded by a crossbar which can be lowered or raised to any desired thickness. The advantage of such an instrument is obvious in that long sheets of skin can be obtained and no adhesives are necessary. The use of the dermatome also has a distinct advantage in that the operator is able to obtain skin from any curved surface, such as the chest wall, which normally would be very difficult to obtain with a free blade.

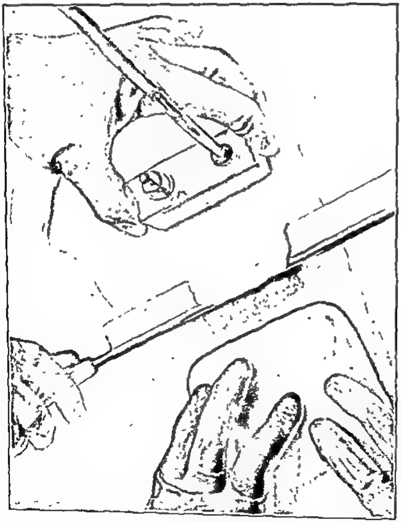

Fig. 156—Cutting thick split graft from thigh according to Blair, using suction retractor

Following the removal of the skin, the donor site is dressed with one layer of scarlet red gauze over which is placed a plain gauze dressing. This is usually left in place for two weeks, after which time all dressings can be removed. The wound is at this time usually covered by epithelium.

Epidermal grafts should normally be 0 0010 to 0 014 inch in thickness. These grafts may be laid on the recipient site covered with one layer of scarlet red or fine mesh gauze. They can be immobilized by using external gauze bandages. How-

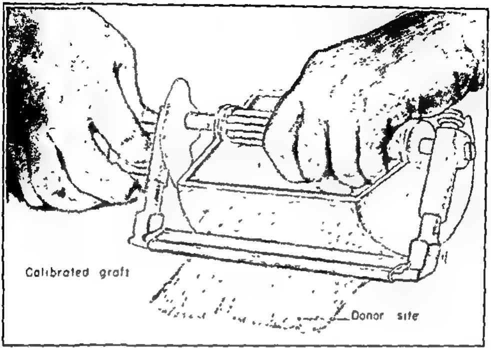

Fig. 157.—The skin adheres to the dermatome by glue adhesive. The drum is revolved upward as the blade is moved transversely. The desired thickness is obtained by predetermined distance of blade from the drum

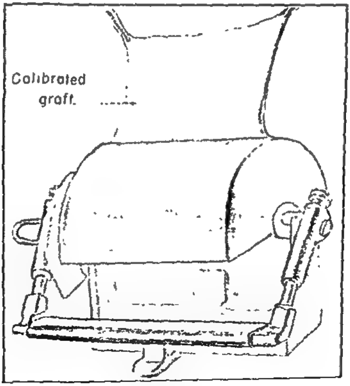

Fig. 158.—Skin is removed from the drum by elevating it with forceps and wiping the glue from its surface with dry gauze.

ever, in most instances, it is best to suture the edge of the graft to the surrounding edge of the skin with fine four 0 or five 0 silk. While this is not always necessary, it is a measure of safety that will give an added insurance against loss of the graft by movement of the transplant.

The aftercare of epidermal grafts is quite simple. The fixation bandages are left in place until the fifth to the seventh day. If there is any evidence of complication, as has been described above, the dressing should be removed prior to this time. At the end of the seventh day all bandages may be removed and the graft gently sponged with 50 per cent hydrogen peroxide to remove any excessive amount of exudate which may have accumulated along the edge of the graft. Inspection should also be made for any evidence of sloughing. If any area of the graft has sloughed, this should be dissected away with scissors, care being taken not to injure the surrounding healthy graft. If this is not done at this time, the products of decomposition of the slough will almost certainly injure the surrounding normal tissue. Subsequent dressings should be of fine mesh or scarlet red gauze next to the grafted surface with a moderate amount of pressure to prevent excessive trauma. All sutures are removed, usually between the seventh and tenth days, depending entirely upon whether the danger of shifting of the graft is present. Dressings are then changed every forty-eight hours until the third week, following which the graft should be sufficiently healed to require no further protection. As has been stated before, it is to be expected that the grafts will undergo some contraction, depending upon whether the underlying bed is loose or rigid. If it is loose, such as muscle or fat, frequently these grafts will undergo as much as 50 to 75 per cent shrinkage. If the graft is placed over a rigid surface, contraction will not be as great. These grafts will not withstand trauma, such as would be received on the hands and feet, and if they are applied to those regions subsequent ulceration may be expected. The epidermal grafts are excellent for lining cavities and for substitution of the mucous membrane in the oral cavity.

Small Split Thickness Grafts

Small split thickness grafts, or the so-called Reverdin grafts, consist of small areas of epidermal skin, and are sometimes known as pinch grafts. There is very little difference in the characteristics or indications between these and the small full thickness grafts, except that there is a higher percentage of "takes" and occasionally they may be used as buried or seed grafts where the excessively thick granulations are present. These grafts will grow on raw or granulating surfaces. Just like large epidermal grafts they will take better upon granulating surfaces that are thin and noninfected. They are used mostly to cover surfaces which are moderately infected and as emergency grafts in larger denuded areas where quick epithelization is desired. They have the distinct disadvantage in that they react poorly to trauma and the areas between the grafts are covered with fibrous tissue. An advantage is that large areas can be covered with skin received from a relatively small donor site. Frequently, following application of these grafts in infected areas, hot wet saline dressings may be started immediately and changed at the end of forty-eight hours. At this time grafts which have not become definitely adherent should be removed. These wounds are dressed at the end of every forty-eight hours until complete epithelization has occurred. Small split grafts are obtained by piercing the outer layer of skin with a straight sewing needle and elevating the point so as to produce a tenting of the adjacent skin. With a sharp knife, the apex of the

pyramid is removed (Figs. 159 and 160) The donor sites, following removal of the grafts, are covered with hot saline packs until bleeding is controlled and then covered with scarlet red or fine mesh gauze over which plain cotton gauze is applied.

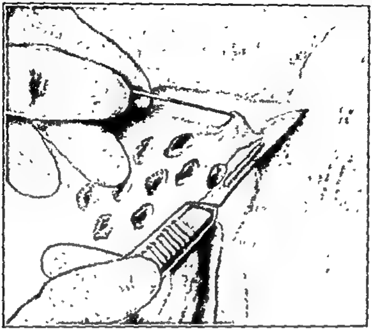

Fig. 159—Method of cutting small grafts.

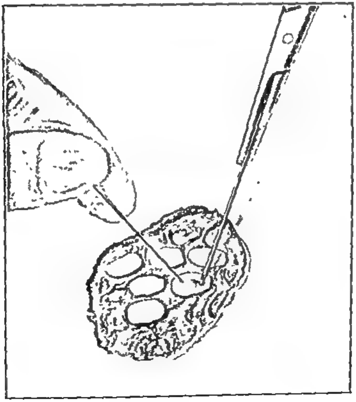

Fig 160—Method of placing small grafts

Intermediate Grafts

Intermediate grafts are thick split grafts and are the most widely used skin grafts today. This is because their physiologic characteristics are such that they

will give the desired covering and, at the same time, the donor site will heal spontaneously. These grafts should range from 0.014 to 0.024 inch in the male and from 0.010 to 0.016 inch in the female. This graft has the distinct advantages of not becoming as discolored as the full thickness graft, retaining its elasticity, being resistant to trauma, and approaching the normal surrounding skin in appearance. These grafts may be placed anywhere on the body and are frequently used to cover defects of exposed surfaces of the face and hands. They take best on denuded surfaces or those surfaces from which the granulating tissue has been removed down to a fine scar base. Great care has to be exercised in the elimination of infection, and hemostasis should be absolute before application of the graft is carried out.

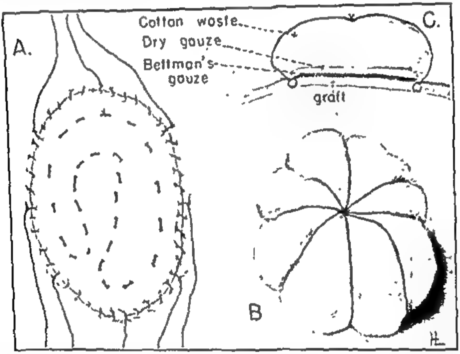

Fig. 161.—*A*, The graft is placed on the recipient site and the edges are united to the adjacent skin with interrupted and continuous *sutures of silk*. The center part of the graft is sutured to the underlying surface with a basting suture of silk. *B* and *C*, The graft is covered with a layer of Bettman's gauze, over which is placed cotton waste. The long ends of the interrupted sutures are tied across to assure pressure and immobilization of the graft.

The *removal* of these grafts is the same as that described above for the epidermal grafts, and they may be taken with a free knife or with a dermatome. Immobilization of these grafts is a necessity to insure successful "takes," and they should be cut to the pattern of the defect they are to cover. The skin edges and graft should be united with interrupted and continuous four 0 or five 0 silk (Fig. 161, *A*). Firm pressure is made over the *entire* grafted area to remove from under the graft air bubbles or pockets of blood and serum. When large areas are covered, the graft should be sewed to the *underlying* bed *with* interrupted or continuous basting stitches to assure further immobilization. The surface is covered with fine mesh or scarlet red gauze and pressure bandages are applied.

There are several methods of assuring pressure. The best is by the use of cotton waste placed over the entire graft and extending on to the adjacent skin areas. This waste is then held *against the site* by external adhesive and elastic bandages. Sea sponges or rubber sponges may be used in place of waste if so

desired. One simple technic of assuring immobilization, and at the same time securing pressure, is to leave the ends of the interrupted sutures between the skin and graft long and to tie them across the gauze waste placed over the graft. This procedure is particularly useful where external bandaging will prove impractical or difficult (Fig. 161, *B* and *C*).

There have been various technics of plasma fixation of grafts devised. The method described by Sano, in which heparinized plasma is applied to the recipient area and a white cell extract in Tyrode's solution is applied to the undersurface of the graft, received favor for a time. These technics have been used by us repeatedly without offering any advantage over those of external fixation described above. In addition there was definitely a higher percentage of "non-takes" unless other fixation procedures were used at the same time.

Bandages upon intermediate grafts should not be disturbed until at least the seventh day, at which time the grafts are dressed and cleansed gently with 50 per cent hydrogen peroxide solution. If healing is progressing satisfactorily, one-half of the sutures are removed, including those in the center of the graft. The remainder are left in until the tenth to fourteenth day. Any area of definite sloughing should be removed by sharp dissection, care being taken to produce a minimal amount of bleeding. Pressure dressings are reapplied and are changed every other day until healing is complete After a period of six weeks, the graft should be massaged with cocoa butter to lessen the amount of rigidity and also to stimulate the circulation. This therapy should be given for fifteen minutes every day for the next eight weeks.

Dermal Grafts

Dermal grafts are the split skin grafts which do not include any epidermal surface. These should be obtained from non-hair-bearing areas and are used as buried grafts to substitute for the loss of subcutaneous tissue and occasionally for supportive cartilage and bone about the face. The prerequisites for their use is that the area into which the transplant is to be placed is free of infection and absolutely dry. Needless to say, the blood supply of the surrounding tissue should be adequate to permit healing of the tissue transplant.

Technic for Removing Dermal Grafts.—The procedure of choice in taking dermal grafts is by the use of the dermatome. With this instrument the epidermis is removed from the donor site and then in turn taken from the drum and saved. The rest of the thickness of the skin on the donor site is removed in the same way as a full thickness graft, that is, the edge of the graft is caught with hooks and elevated, and with a sharp knife the undersurface of skin is dissected from the subcutaneous tissue. The entire graft is thus removed and the raw surface of the donor site is covered with the epidermis which has been saved If the graft is large, the epidermis may be sutured to the surrounding edge of the skin with interrupted and continuous four 0 or six 0 silk sutures. The site is then covered with scarlet red gauze and dressed with pressure bandages and gauze waste. The dermis is ready for transplantation.

Dermal grafts are used in small depressions occurring in the subcutaneous tissue of the face rather than transplanted fatty tissue. They are used to fill out slight depressions of the dorsum of the nose and also depressions of the upper lid

following removal of the globe. The skin over the area is dissected free of the underlying subcutaneous tissue. The dermal graft may be placed in layers or folded to conform with the shape of the depressed area. The incision is closed with fine silk sutures and a moderately firm pressure is applied over the grafted area for a total of ten days. Following implantation of such grafts, the entire area will be indurated for varying periods of time, usually three weeks. One must be on the alert for fluctuation, as this denotes an accumulation of either serum, blood, or pus. A diagnostic aspiration, using a small needle, should be made. If pus is present, the graft should be removed; if serum or blood is present, repeated aspirations are necessary to assure healing of the underlying graft.

FULL THICKNESS GRAFTS

Full thickness grafts consist of the entire full thickness of skin devoid of all subcutaneous tissue. Physical properties of this skin following a succesful "take" are the same as that of normal skin. If hair follicles are included in the graft, the hair will grow just as before it was transplanted; therefore, if a full thickness graft is used to cover areas in which the hair is normally not present, a suitable site devoid of hair should be chosen for the donor area. Conversely, this property is of definite advantage in the transplantation of the full thickness scalp graft for the formation of eyebrows. One great disadvantage of full thickness graft is that frequently when skin is taken from an unexposed portion of the body and transferred to that of the hands and face where exposure is constant, the entire graft may be subject to an increased deposit of pigment, brownish in color, which may prove unsightly. Because of the thickness of the graft, the demand for early blood supply is greater, and a successful 100 per cent "take" is not as frequent as that of the split thickness graft. Often at the first dressing one finds desquamation of the epithelium of the entire graft which is attributed to the failure of early vascularization with superficial epithelial loss. This does not mean that the entire graft will not live as regeneration of an epithelial covering will occur. Full thickness grafts will not take on granulating surfaces and should granulation or excessive scar tissue cover the recipient area, it is necessary that all of it be removed down to a normal healthy bed of soft tissue before the graft is applied. Absolute success can never be obtained where infection is present. Because complete vascularization is necessary, a longer period of immobilization is required. There is always danger of degeneration of the skin from too early dressings and other trauma which may damage the blood supply.

The method of obtaining a full thickness graft is quite simple. (Fig. 162.) Following the removal of all granulating and scar tissue from the recipient area, a pattern is made, outlining the contour of the defect. The material for this may be rubber tissue, paper, paraffin gauze, or metal foil. The pattern is placed over the donor site and the skin around it is outlined with a sharp-pointed knife. The full thickness of the skin is incised and its edges are picked up by small forceps or hooks and rotated upward so as to expose the underlying surface. Using a sharp knife, all of the subcutaneous tissue is removed and the complete graft is dissected out.

The graft is placed into its correct position in the recipient site and its surrounding edges are sutured to the adjacent skin with interrupted and continuous four 0 and six 0 silk. Here as in thick split thickness grafts, immobilization may be

obtained by using a basting or interrupted suture in the center of the graft if external immobilization cannot be adequately applied. Caution should be used against the collection of serum, blood, and air beneath the graft and these should be expressed before the dressing is applied.

The bandages should be left on the graft for seven to ten days and following their removal all desquamation should be cleared away. If healing has taken place, one-half of the sutures may be removed and the remainder left in from ten to fourteen days. Pressure bandages should always be used for a period of fourteen to twenty days, depending entirely upon the progress of the healing of the wound. The donor site can be closed usually by undermining the skin edges and suturing these together with silk sutures Occasionally, where large areas of full thickness skin have been removed, the donor area may be covered with split thickness grafts removed from another site.

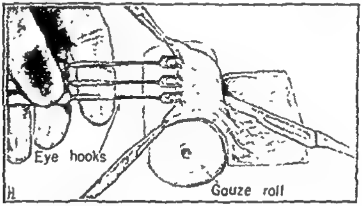

Fig. 162.—An outline of the area of skin to be removed is incised The edges are dissected up with a sharp knife and caught with clamps or hooks and carried backward over a small roll of gauze as the dissection progresses.

Small Full Thickness Grafts

Small full thickness or Davis grafts are used on large granulating areas in which the granulations are no higher than that of the surrounding skin and are healthy in appearance. These should never be placed upon exuberant granulating tissue. The only advantage of this graft over the small split thickness graft is that there is less subsequent contraction of the grafted area and the wound is more resistant to trauma The percentage of "takes" is never as high as that of the small split thickness graft. Firm pressure fixation should be used for at least four to seven days

The method of obtaining these grafts is by inserting a straight sewing needle into the full thickness of the skin, drawing it upward, and amputating the base of the cone (Figs 159 and 160). This will enable the operator to obtain a small circular area of full thickness of skin. The donor site is covered with scarlet red or fine mesh gauze over which gauze dressings are applied and left for two weeks before dressing. At the end of this time complete healing has usually taken place. The aftercare of the grafted site is the same as that described for the small split thickness grafts

Sieve Grafts

In 1930 Douglas described the technic and application of the sieve graft This consists of a full thickness graft that has circular punched-out areas throughout,

measuring approximately 3 to 4 mm. in diameter. These areas are left intact at the donor site to act as nuclei about which epithelization will take place. The technic for obtaining these grafts is the same as that for the full thickness, except after the pattern has been outlined on the normal skin these small circular areas are cut through the graft using a circular die (Fig. 163). In dissecting the full thickness of the skin upward, the small circular areas of skin are left intact. The application of the sieve graft to the recipient site is the same as that of the full thickness graft. It offers, however, no real advantage over that of the normal full thickness graft as a covering and is not practical for the best cosmetic appearance since the small circular areas have to heal by epithelization, producing an unsightly mottling. It does have an advantage in that the islets are left intact on the donor site, thus eliminating the problem of closing the wound (Figs. 164 and 165).

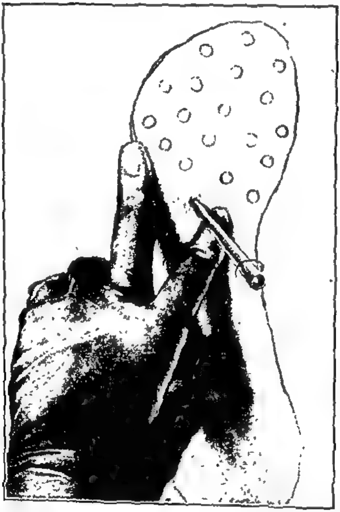

Fig 163 —Steel die boring out islands of skin at equal distances from each other throughout the outlined donor site of the graft The surrounding skin is held at tension with the fingers (Horsley, John S, Jr · *Internat S Digest 16*. 67-82, 1933)

TUNNEL GRAFTS

Tunnel grafts are embedded beneath the skin, scar, or open wound and may be either full thickness or split thickness grafts of skin. They are indicated most frequently in areas which have excessive amounts of scar tissue and are chronically infected. Free grafts used on these surfaces would have a relatively small chance of taking unless they were thin. The tunnel or cavity is prepared as follows, be-

neath the area which is to be grafted: An incision is made along the edge for the entire linear distance of the wound. By carefully cutting beneath the surface and paying particular attention not to invade the overlying wound, a cavity is produced which extends under the entire area. All bleeding is controlled by fine catgut ligatures or the application of hot saline packs. A thick split thickness graft or a full thickness graft is taken from the donor site and wrapped around a stent made of dental compound which has the contour of the cavity into which the graft is to

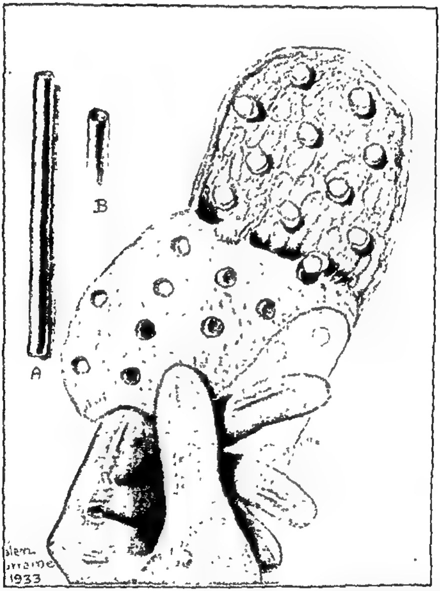

Fig 164.—Showing the dissection of the sieve graft from the donor site leaving small islands of skin equally spaced. Note the discoloration of the subcutaneous tissue around the punched-out arch. *A* shows Douglas' steel die used in cutting out islands—longitudinal view. *B* shows the oblique view of the die with the cupped cutting point The cutting edge of the standard die measures ¼ inch in diameter and its flange is 1/16 inch deep. (Horsley, John S, Jr.: Internat. S. Digest 16: 67-82, 1933).

be placed. The graft about the stent is taken as one piece and its ends are sutured together over the stent with continuous or interrupted four 0 silk. This graft is placed into the cavity and the edges of the wound are sutured together with interrupted four 0 silk The graft is left in place for ten days. The sutures are then removed along the previous line of incision and the stent is removed. The area

over the lined cavity is removed along with the immediate underlying graft, thus unroofing the entire area and leaving the graft along the base and sides of the cavity intact. This is then dressed with moderate pressure every other day until the graft is entirely healed.

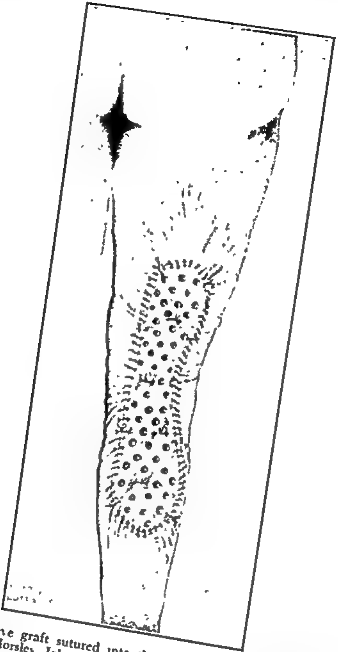

Fig 165.—Showing the sieve graft sutured into the wound of the posterior thigh, popliteal space, and leg (Horsley, John S., Jr.: Internat. S. Digest 16: 67-82, 1933.)

COMPOSITE GRAFTS

Composite grafts are grafts in which both surfaces are covered with normal skin and there is cartilage and subcutaneous tissue between the two layers of skin. These are secured from the margin of the ear and are used to rebuild the ala of the nostril and also sections of the lower eyelids. In reconstructing the rim of the nostril, the edges of the defect are freshened by denuding all scar tissue. The pattern of the defect is outlined with metal foil. This pattern is placed over that portion of the helix of the ear which will most closely conform to its outline. A wedge

conforming to the pattern is removed. The resulting wound of the ear is closed in layers and the free graft is implanted into the defect of the nose; the skin on the undersurface of the graft is sutured to the skin of the inside of the ala, and the skin on the outside of the graft is sutured to the skin of the outside of the ala, as shown in Fig. 262, Chapter 21. The graft should have adequate support on both surfaces. This can be obtained by packing the nostril inside with petrolatum gauze and using intranasal gauze splints. The outside can be immobilized with adhesive strapping placed over fine gauze dressing. This support is left in place for two weeks, following which all dressings are removed and one-half of the sutures are taken out. The remainder of the sutures are left in for eighteen to twenty days. The most important points in the technic of these grafts are the accurate suturing of all skin surfaces to the graft and the maintenance of supportive immobilization both inside and outside of the nostril.

MUCOUS MEMBRANE GRAFTS

At the present time mucous membrane grafts are used rarely. They are still used for the lining of the eye socket or the replacement of the mucosa of the mouth following removal of scar tissue formation. The method used in lining the eye socket is to remove all scar tissue from the orbit, producing a cavity which is at least one-half again as large as that of the normal eye. The full thickness mucous membrane is removed from the inner surface of the cheek, taking care not to leave any adjacent submucous tissue on the graft. The resulting wound of the cheek is closed primarily with four 0 silk sutures. The graft is sutured with fine silk over a dental compound mold, the size of the orbital cavity, the epithelial surface of the graft being placed next to the mold. The mold is made by melting dental compound (Kerr black impression tray compound) in warm water and, while it is still soft, placing the required amount into the cavity. The graft-covered mold is placed in the orbit and the lids are sutured over it with interrupted four 0 silk sutures. This is left in place for ten days, at which time the sutures are removed from the eyelid and the stent is taken out The area is cleansed with 50 per cent hydrogen peroxide every day and the eye is rebandaged with the stent in place for a period of not less than two or three weeks until all healing has taken place.

In cases of scar tissue contraction within the mouth, all scar tissue is first removed. The defect is lined immediately with a full thickness mucous membrane graft from the opposite cheek, which is sutured in place over a compound stent the size of the cavity. The edges of the adjacent normal mucosa are closed over the graft-covered stent and left for seven to ten days, at which time the sutures are removed and the stent is taken out. Because of the scarcity of the mucous membrane in the mouth, if the defect is of considerable size a split thickness graft of non-hair-bearing skin is preferred in most cases.

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CHAPTER 18

DEEP TISSUE GRAFTS

LEROY SMITH

FAT GRAFTS

The use of fat as a free graft in filling out defects, particularly on the face, has been carried out with some success for a long period of time. Experimental work has shown that in most of the transplanted fat which "takes," the cells remain as the original fat that has been transferred. However, some of the fat will undergo necrosis and is replaced with fibrous tissue, causing a diminution of the total volume of transplanted tissue. Peer has shown that small fat transplants will lose 79 per cent of their weight and volume and large transplants will lose up to 45 per cent To allow for this, it is essential when these grafts are used that at least one and one-half times more desirable fat be transplanted in order to secure the necessary permanent amount. It is also necessary that the cavity into which the fat is to be placed should be free of infection and the blood supply adequate. At the time of transplantation, a meticulous sterile technic must be used. The fixation of grafts should always be done, and when possible transplantation should be carried out through an incision which does not overlie the graft. The best source of fat is the subcutaneous tissues about the buttock, thigh, and abdominal wall. Another source, rarely used, is omental fat. Because of the uncertainty of the amount that will survive, the use of derma, cartilage, and bone has largely replaced fat as a contour graft.

Technic of Fat Transplantation

The outside skin of the defect should be thoroughly sterilized with antiseptics and the incision should be made along the edge of the defect where possible. This incision should be adequate for insertion of the graft without traumatizing it. The overlying skin should be elevated by sharp dissection and hemostasis carried out by fine catgut ligatures of 000 plain catgut and by hot saline sponges inserted into the cavity. The area to be grafted should be filled out to the desired contour with gauze. The gauze is removed and the total volume of fat necessary is estimated As has been explained previously, the graft should be at least one and one-half times as large as actually needed to fill out the defect In most instances, fat the thickness of the abdominal wall is satisfactory. If excessive thickness is necessary, the upper outer quadrant of the breast of the female or the upper outer quadrant of the buttock of either the male or the female may be used An incision is made through the skin the length of the diameter of the graft The skin is undermined and the perimeter of the graft is outlined by an incision carried through the fat

down to and including the fascia of the muscle upon which it rests. The fascia and underlying fat are then removed as a whole graft, and the donor wound is closed. Small linear incisions are made in the fascia of the graft about 1 cm. apart to allow the fat to bulge through. The graft is closely inspected and all globules are removed from the surface in so far as possible. The less oily surfaces present the better chance for a successful "take."

Inclusion of the underlying fascia, where possible, is a great aid in fixation of the transplant. Interrupted four 0 silk sutures are passed through the edges of the fascia at intervals of 2.5 to 5 cm. If fascia is not present, the threads are placed in the edge of the fat. The graft is placed into the cavity and the long ends of the sutures on the graft are threaded on a straight needle and carried through the overlying skin as the graft is inserted into the cavity. The sutures are tied over a small gauze bundle to prevent cutting through the skin. By this method there is a minimal amount of motion, and fixation of the entire graft is assured. The original incision is closed with interrupted four 0 silk sutures. A small rubber tissue drain is carried down to the graft to allow the escape of any serum that forms, and a soft gauze pressure bandage is applied over the grafted site and secured by an elastic bandage or adhesive strapping. This area is not dressed until the fifth postoperative day, at which time the drain is removed if there are no areas of fluctuation or infection. The graft site is dressed again with pressure bandages and redressed every forty-eight to seventy-two hours thereafter. The sutures about the graft are removed at the end of the tenth postoperative day. Support of the graft should be carried out for at least two weeks, after which time there is usually enough fixation so that further dressings are not necessary. In most instances there is a moderate tissue reaction to the transplant. The area about the graft becomes indurated and is marked by redness and edema of the skin. This may continue for four to eight weeks but does not necessarily indicate that the graft will be lost. Sometimes there develops in the site hard nodular areas which may or may not be painful. These are usually areas undergoing necrosis and do not need special treatment unless there is definite fluctuation. If such is the case, the skin should be excised to allow for the escape of serum and oil from the indurated area. As has been noted, the entire graft will shrink and this shrinkage will continue for about a year. In instances in which there is generalized infection of the wound nothing is gained by conservative treatment, and when gross contamination occurs the entire graft should be removed to facilitate rapid healing.

FASCIA GRAFTS

Of all tissue used as a transplant, fascia is the most satisfactory. Histologic examination following transplantation reveals there is little, if any, cellular change and it retains its strength The weakest point in its use is where its ends are united to other tissue This union has to be secure or it will separate under stress. For this reason all points of approximation should be sutured with nonabsorbable material and the contact between the fascia and the tissue to which it is united should be free from excessive stress until healing has occurred

Fascia is used to repair injuries in tendons, muscles, and bone, and as a support to tissue following paralysis of muscles. Frequently it is used as a living suture in repair of hernias and joint capsules.

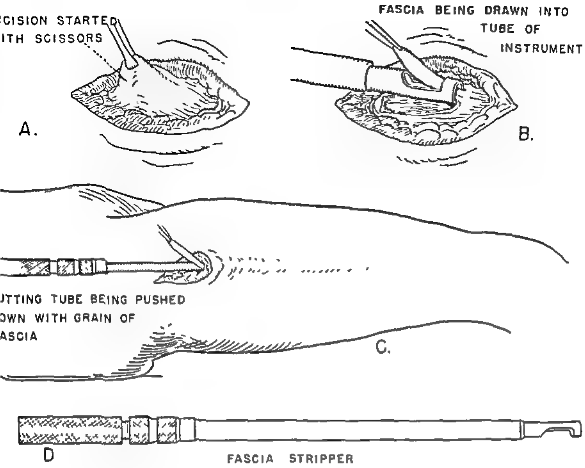

Fig. 166.—Technic for removal of fascial graft with fascial stripper.

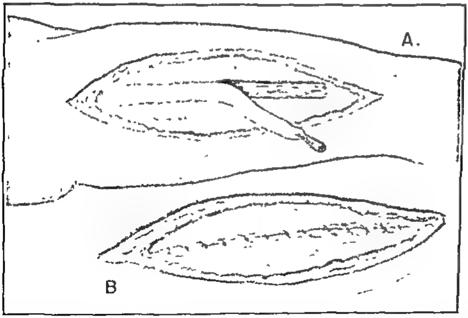

Fig. 167.—Method of obtaining large grafts from fascia lata. *A*, Incisions must be made ▪ entire length of the desired graft The soft tissues are dissected from the fascia The nount of necessary fascia can then be dissected from the underlying muscle *B*, The wound the fascia ▪ closed with continuous *silk or catgut sutures, thus preventing herniation*

Grafts of fascia are readily obtained from the fascia lata of the thigh, although fascia of the abdominal wall can sometimes be used. In obtaining a graft from the fascia lata, there are two choices of technic. One may make a small incision over the upper outer thigh, exposing the fascia, and then thread a small width of fascia on a fascia stripper (Fig. 166). This is forced downward along the thigh with the grain of the fascia until the desired length is obtained. At this point, a small incision is made and the fascia is cut at the end. Some strippers are made with a blade which will cut the distal end without necessitating the second incision. When this procedure is used, a hematoma may develop unless firm bandages are applied after the fascia is removed. If a wider graft is desired, the fascia stripper cannot be used and the skin incision must be long enough to expose the whole area to be removed. This technic also permits closure of the fascia wound over the muscle, although this is not necessary as muscle hernias do not usually give trouble. (Fig. 167.) The blood supply is not as important in the transplantation of fascia as it is for other transplanted tissue. The fascia is inserted into the defect and sutured to the adjacent tissue with sutures of cotton or four 0 black silk. As has been stated, it is important to obtain a firm union between the fascia and ends of the tissue to which it is sutured; otherwise, particularly if there is much stress, the graft will pull loose. To avoid this, the fascia may be overlapped at its end in order to make the graft thicker at this point, enabling the sutures to have a firm hold (Fig. 254, *A*). If fascia is used for supportive measures, such as hernias, and ptosis of the face following fascial paralysis, it is helpful to have these parts fixed in a relaxed manner by outside adhesive support for at least two weeks until the fascia graft has had an opportunity to heal (Fig. 221).

MUSCLE GRAFT

Muscle used as a free transplant is unsatisfactory. It will usually not live but undergoes fibrous degeneration. If one expects a transplant to live, the area into which it is to be placed must have adequate blood supply, and immobilization of the graft is imperative. The thinner the graft, the more successful the healing will be. Grafts over 1.25 cm. in thickness are almost certain to meet with failure. A muscle graft is easily obtained from the outer edge of the pectoralis major muscle through a linear incision along the anterior portion of the axilla. From this region almost any desired size and shape of muscle can be obtained. The muscle of the buttock and anterior abdominal wall also may be used. Such transplants are satisfactory in filling out defects resulting from tissue loss about the face and concave defects of the extremities. The site into which the transplant is to be placed is exposed through an incision at the periphery and should be long enough to admit the entire graft without traumatization. The pocket is dissected out in the subcutaneous tissue and the free bleeding is controlled with fine plain catgut ligatures. The muscle graft, which normally should be one-half again as large as is necessary, is placed into the cavity so that it will be smooth and the entire outside will be in contact with the surrounding subcutaneous tissue. The graft may be immobilized by suturing it with fine silk sutures passed through the outside skin and graft and tied over small pledgets of cotton. These should *not* be unduly tight but snug enough to prevent motion of the muscle following the implantation. The wound is closed in layers and a moderate amount of external pressure is made by

placing gauze waste over the site, and this is strapped with adhesive or elastic bandage. These wounds are usually not dressed under seven to ten days unless there is an elevation of temperature or an undue amount of pain and edema about the site, in which case exposure of the area should be made. If there is evidence of fluctuation or infection, the muscle should be removed. Following the healing of the wound, a moderate amount of induration and edema is to be expected for a period varying from two to three months. Some shrinkage of the graft is to be expected for twelve to eighteen months.

CARTILAGE

Cartilage is an excellent supporting tissue which is readily available for grafting, and it "takes" well in almost any sterile wound. Partial or complete loss will follow if the cartilage is injured, if dead spaces exist, or if infection occurs. Otherwise it may persist indefinitely without any alteration in its size in spite of subsequent fibrous and calcification changes. It is used to fill out defects of hard tissues such as saddle nose deformities, sunken areas on the face, and cranial defects. Cartilage that has been transplanted unites with bone only by a dense fibrous connective tissue union. It can be angulated, curved and transplanted in nearly any shape, and will "take" and remain in that shape. The perichondrium, which may or may not be transplanted with the cartilage, is useful as a hinge when the graft is angulated, as in the nasal bridge and columella, and is helpful in suturing. Autogenous cartilage grafts are preferable, but living and preserved isografts have been used apparently with success by a number of operators.

The three chief sources for cartilage grafts and transplants in order of their importance are: ribs, ears, and nose. Cartilage can be obtained from either costal margin. (Fig. 168)

The hyaline costal cartilage is by far the most suitable substance for reconstructing defects of the supporting structure of the face. It is relatively easy to get in good quantities and is readily trimmed to the proper shape and size. It is obtained by making a slightly curved or longitudinal incision about 8 cm. long, 8 to 10 cm from the midline, with the lower part of the incision extending over the costal margin. The fascia and rectus muscle are separated longitudinally, exposing the lower costal cartilages. A sufficiently long piece of the seventh, eighth, or ninth cartilage, including the perichondrium, is removed. If wider pieces are required, the fused cartilages of the sixth and seventh are utilized. Injury to the internal mammary vessels and the pleura should be avoided. Where the plan of operation calls for a cartilage supply at various stages, it is advisable to remove all the cartilage needed at the first operation. The surplus is transplanted and stored at some accessible site beneath the skin in the subcutaneous tissues. Later on when further cartilage is required, it is easily obtained by a simple operation under local anesthesia. The chest wound is closed with buried catgut sutures and the skin is sutured with silk. If hemostasis is difficult, it is advisable to insert a small drain, which is removed in twenty-four to forty-eight hours. A firm pressure dressing is applied and fixed with long wide strips of elastic adhesive plaster coursing parallel to the ribs in a manner similar to strapping for a fractured rib. The cartilage is then trimmed to the exact size and shape to fit the defect. A wax or wooden pattern prepared before the operation is helpful as a guide in this part of the operation

The natural curve of the cartilage may be used in reconstructing a curved outline, such as an ear. Care is necessary to prevent the tendency for the formation of a curve in the cartilage subsequent to its transplantation. Any curving tendency should be noted before placing a graft in the wound and corrected by removal of or by transverse incisions through the perichondrium, and by notching the cartilage. After the graft is inserted, it is fixed by a few plain catgut sutures through the perichondrium or about the cartilage, but not through the cartilage, as this may weaken the graft or cause an undue local reaction. The wound is then closed and the part is gently immobilized by a sea sponge, well-padded dressing, or malleable metal splint.

Cartilage can be obtained from the ear or nose and used for grafting for supporting tissues, but the supply is small and when transplanted this yellow elastic cartilage is more friable and less stable than the hyaline cartilage from the ribs. Occasionally, however, this cartilage may be used in very small defects such as in the ala of the nose. A graft of ear cartilage can be removed under local anesthesia through a short incision over the tragus, leaving an inconspicuous scar.

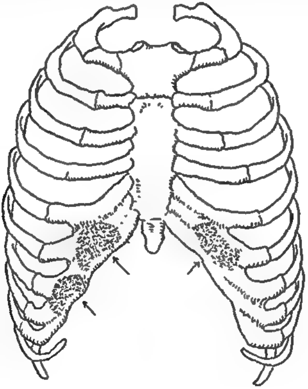

Fig. 168.—Sites preferred for removal of costal cartilage.

BONE GRAFTS

The use of bone as a free transplant is indicated when replacement of normal bone and, sometimes, cartilage is desired, although valuable substitutes, such as stainless steel, Vitallium, celluloid, and other material, have been tried. *Nothing to date has supplanted the satisfactory results obtained with autogenous bone.* During the last few years with the advent of bone banks, a wave of enthusiasm has been noted for homogenous transplants. It now becomes apparent that these grafts do not survive and later will all have to be replaced. Homogenous bone transplants have *no substantial place* in plastic and reconstructive surgery.

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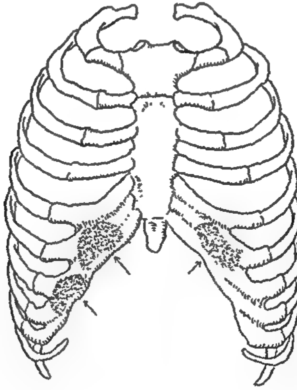

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Much controversy has been carried on as to the physiology of bone grafts. It is now believed that when viable bone is transplanted it undergoes degeneration, but at the same time and at the same pace new bone is formed. Various factors influence the rate at which this transition takes place. They are adequate vascularization of the surrounding soft tissue bed, firm attachment to normal bone when possible, immobilization, and good general condition of the patient. The presence of periosteum is not necessary but will hasten the viability of the graft.

The relative merits of the two types of bone grafts have been often discussed. There are certain advantages of both cancellous and cortical bone. Cancellous bone is more pliable, is resistant to infection, and requires less blood supply than cortical bone. However, it will undergo some loss in weight and volume through absorption. Cortical bone is more easily obtained, is rigid, and will not lose its contour or volume if a favorable take is obtained.

Technic of Obtaining Bone Grafts

Care in the choice of bone is essential for good results (Fig. 169). In replacements which require stress, rigidity, and a minimum of absorption, cortical bone should be used. In cases of questionable blood supply, cancellous bone is best. Cancellous bone is obtained from the iliac crest. A linear incision is made over the external iliac crest extending from the anterior superior spine upward and outward along the rim of the ilium. The soft tissues are dissected from the inner surface of the ilium and a window measuring 2 to 5 cm. in diameter is made just at the edge of the crest. With a bone curette, all of the cancellous bone between the two tables of the ilium is removed. Frequently one side will not contain quite enough, in which case the opposite side can be used. The bone is then placed in a moist saline sponge, all blood and serum are removed, and the bone is compressed so that a correct estimate can be made of its volume. The wound of the iliac crest is closed in layers with 0 fine plain catgut in the subcutaneous tissue and interrupted four 0 silk in the skin A rubber tissue drain is placed in the wound and left in place for forty-eight hours. In transplantation of cancellous bone, the pocket should be made through an incision which does not lie directly over the site the bone is to fill out. The skin and soft tissue are elevated and the cancellous bone is packed into the cavity, slightly in excess of the amount necessary. The wound is closed with interrupted four 0 silk without drainage The desired contour of the underlying graft is molded by hand and held in place by a dental compound or plaster of Paris splint Such supports should remain for ten days, at which time the graft has become fixed to the surrounding tissues There will always occur a slight amount of bone absorption, and, if the graft has been placed near the skin, there may be some irregularity noted over the surface This will eventually become smooth. However, if any large deposits of the graft are in evidence, these may be removed with a bone file at a later date.

There are several suitable sites from which the operator may obtain cortical bone. Usually the ribs, iliac crest, or anterior tibia are used When small thin cortical bone is needed, as sometimes is necessary for replacement of bone loss from the dorsum of the nose or around the orbits, rib grafts are best These are obtained through an incision over the seventh, eighth, or ninth rib in the anterior chest well The periosteum is incised and stripped upward with periosteal elevators. With a

curved periosteal elevator extending under the rib, the posterior surface of the rib is freed and the rib is removed according to the length desired. The wound is closed in layers with catgut in the fascia and subcutaneous tissue and interrupted four 0 silk in the skin. The graft is shaped to conform to the desired contour and implanted beneath the skin and subcutaneous tissue. Where possible, it is desirable to fix the graft to the underlying bone; however, small bone grafts resting in the subcutaneous tissue will "take" satisfactorily.

Bone grafts from the iliac crest are secured through an incision over the iliac crest extending along the rim. The periosteum is elevated on both sides. The desired amount of bone is removed with saw or chisel. This type of graft is adaptable to replacement of losses of the mandible, as will be described in a subsequent chapter. The resulting wound is closed in layers as has been described.

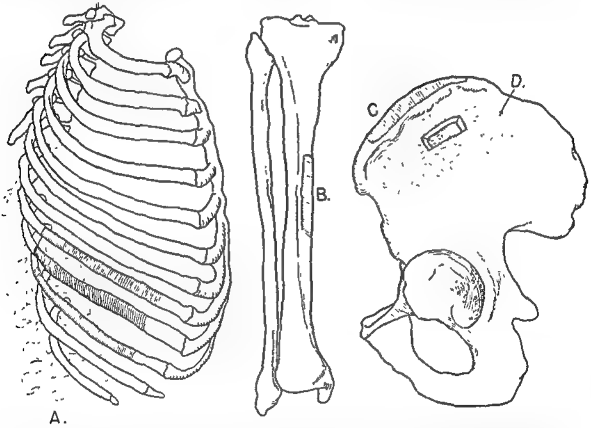

Fig. 169—Sites of obtaining cortical and cancellous bone. *A,* Whole or partial rib grafts are obtained from the lower ribs *B, Thick cortical bone of almost any length, width,* or thickness is obtained from the anterior surface of the tibia *C,* Site of cortical bone grafts from the iliac crest. *D,* Cancellous bone is obtained through a window made just below the graft in the outer or inner table. Through this window the cancellous bone between the tables is curetted.

Where straight thick cortical bone is desired, the anterior surface of the tibia is the best site from which to obtain it. An incision is made along the anterior tibia for the required distance. The periosteum may or may not be removed and the necessary amount of anterior table is resected with a hammer and chisel or an electric saw. The wound is closed with plain catgut in the subcutaneous tissue and interrupted four 0 silk in the skin. Following removal of such bone, it may be shaped to the desired contour with rongeurs When thick cortical bone is used, it is imperative that the bed of the recipient site should have adequate blood supply and

be free of scar tissue. The ends of this graft should always be in contact with the medullary cavity of the adjacent bone. Immobilization is imperative to prevent nonunion, and the methods of immobilization will be explained in a subsequent chapter.

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CHAPTER 19

CLEFT LIP AND PALATE

LEROY SMITH

Among the most frequently encountered congenital abnormalities to which the human race is subjected is the cleft lip, cleft palate, or both. Surgical repair can be traced as far back as the very earliest medical records. Celsus and other early operators submitted procedures of closure of facial clefts, particularly those of the upper lip. Credit for the present-day results should be given to the efforts of the many interested early contributors. In closing the lip, obtaining adequate relaxation to permit approximation of the two denuded edges was greatly aided by Franco, who in 1561 recommended separation of the lips from the maxillary bones. Mirault in 1844 proposed the formation of a lip flap from the edges of the long side of the cleft, which gave the lip more length and fullness. There have been many modifications of this method, those of Giraldès, König, and Hagedorn in 1894, and later of Blair and Brown. At the present time the two most widely used methods of repair of the single cleft lip are the Brown-McDowell modification of the Blair-Mirault operation and LeMesurier's modification of the Hagedorn technic. The progress in developing a satisfactory method of repair for double cleft lips has been slower. This probably is the result of a deficiency of available lip structure Veau, Rose, Federspiel, Barsky, and others have presented operations for closure with but little basic variation.

There is no record of successful cleft palate repair until 1784 by LeMonier, and this was only a closure of a defect in the velum. In later years there has been a continuous presentation of various technics by von Graefe, Warren, Diffenbach, von Langenbeck, Dorrance, Wardill, and others.

In this country, von Langerbeck's operation, or a modification therof, has met with the most favor. A few cases will demand a change to Dorrance's "push-back" procedure or other tried and proved methods that will adequately answer the problem of closure with good function.

Cleft lip, cleft palate, or both together have no known etiology, although many theories have been advanced In modern recorded cases, one is forced to accept the opinion that heredity is the most important factor. Because of no definite pattern or sequence of occurrence, a prediction of the defect can be cited only by the review of statistics. As an average, 1 out of 1,000 white and 1 out of 2,000 Negro newborn infants have this deformity. The occurrence of lip defects is slightly greater than those of the palate. Mütter, in reporting 270 cases of lip cleft, found 170 in boys and 100 in girls. Single lip clefts occurred slightly more than twice as frequently on the left side.

The classification which Ritchie presents is as follows:

1. Prealveolar clefts (cleft lip), normal alveolar process and palate.
2. Postalveolar clefts (cleft palate), normal alveolar process and lip.
3. Alveolar process cleft, cleft of lip, palate, or both with alveolar cleft.

The time for operation in these cases is variable in different clinics. Some surgeons believe closure within the first seventy-two hours for lip defects gives the advantage of least embarrassment to parents, and earlier nursing on the part of the child. However, it is best to wait until the sixth or eighth week after birth, since at this age the child has had an opportunity to get over its initial weight loss, present any other defects, improve its general condition (blood count, feeding habits), and to take a general anesthetic with less danger.

The palate is generally repaired at twelve to eighteen months of age. At this time the child has developed enough to withstand the trauma and blood loss of the operation without serious danger of shock. The time elapsing between the lip and palate operations allows any cleft in the alveolar process to come together and affords the operator an opportunity to close the palate completely at one operation. Nothing can be gained by closing the cleft earlier.

REPAIR OF SINGLE CLEFT LIP

As in other major surgical problems, preoperative preparation is important. In most instances, the child has been under the care of a pediatrician and the general condition is left to his judgment. From a surgical point of view, however, certain physical standards should be met. There should not be any associated congenital defect which would contraindicate surgery Feeding habits must be satisfactory as shown by gain in weight and lack of gastrointestinal upset An operation is never permitted in face of recent infection, generalized or local. Chest x-rays are made to eliminate possible persistent thymus gland enlargement. Some objection has been raised to routine x-ray of the small infant's chest because of the possibility of resulting fibrosis of the lungs, but nothing has been found to substantiate this criticism Kidney function, determined by routine urinalysis, must be normal. Blood examination, in addition to hemoglobin, red blood count, white blood count and differential, should include coagulation and bleeding time. If these are abnormal, or if the hemoglobin is below 70 per cent, the operation is postponed All children should be admitted to the hospital forty-eight hours prior to operation, as this allows time for a complete study and establishment of the nursing routine

In patients up to four months of age no immediate preoperative drug is given Feedings are discontinued six hours before operation and no preparation of the face is necessary Older children receive atropine and an opiate if so desired, according to the correct dosage for their age Drugs should be given hypodermically thirty minutes before anesthesia

Ether spray has proved to be the most satisfactory anesthetic It is the practice with some surgeons to use local infiltration of ½ per cent procaine and with others intratracheal ether The latter has no real advantage except prevention of possible aspiration of blood The face is painted with 70 per cent alcohol, and all crusts about the lips and nostrils are removed.

Before outlining any operative technic, a word concerning the object of a desirable repair should be noted. Regardless of the severity of the cleft, closure should give a normal size and shape to the affected nostril, length, thickness, and fullness of the lower third of the lip, and an even vermilion border which, when possible, should have a Cupid's bow in the center. All clefts, if not extending into the nostril, must be carried there by an incision, as no satisfactory plan can be carried out that does not include the entire length of the lip. Simple excision of even the slightest cleft, leaving a straight scar, will almost invariably produce a notching of the lip edge by scar contraction later.

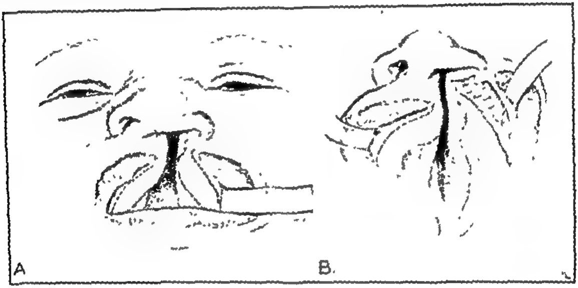

Fig 170 —*A* and *B*, Lines of incision extending along the buccal alveolar sulcus through which the soft tissues over the maxillary bones are undermined.

Regardless of which plan of operation has been decided upon, there are two common conditions which have to be considered: first, relaxation of both sides of the lip so that the edges can be brought together without tension, and second, freeing of the lower lateral cartilage of the nose on the affected side so it may be rotated upward and medially when the new nostril is formed. After the lines of incision are marked on the skin surface, the cleft is completed into the floor of the nostril, if necessary, by incising the full thickness of the lip in the planes of the defect. Both sides are rotated upwardly and outwardly to expose the buccal alveolar sulcus. On the lateral side an incision is made along the sulcus, keeping close to the bone, and extending from the floor of the nostril to approximately one-half the length of the alveolar ridge. The soft tissues over the maxilla are undermined up to the infraorbital ridge and medially over the frontal process. The entire lateral side of the lip can now be brought medially. If further relaxation is desired, the buccal mucosa may be incised perpendicularly to the original incision. Medially the incision extends from the base of the columella under the normal ala posteriorly far enough to bring this part of the cleft into a normal midline position without tension. In wide clefts of the lip and alveolar ridge, the septum is freed from the spine at its base so it may be swung into an upright position. Bleeding is controlled by gauze packing and pressure, and the larger vessels are ligated. To secure freedom of the lower lateral cartilage, the skin overlying it is dissected up with small scissors, passing through the relaxation incision at the base of the ala (Fig. 170). This will allow

the cartilage to rotate up and medially without buckling. It may be noticed that there is a prolapse of the upper lateral edge into the vestibule. To correct this, the excessive amount of mucosa between the lateral wall and the outer upper edge of the cartilage should be removed by a wedge-shaped excision.

The plan of the operation which follows is that of the Brown-McDowell technic with but slight modification. Incidentally, the normal nostril should receive close observation as to height, ala position, and width of the floor. With the medial edge of the vermilion cleft pulled downward and laterally, calipers are used to measure the distance from the normal nostril floor to the vermilion-cutaneous border im-

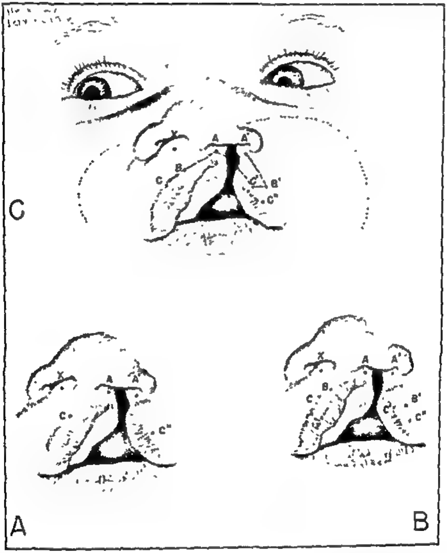

Fig 171 [illegible] *ostril vestibule. A point on the* vermilion-cuta [illegible] This distance is measured with the calipers [illegible] same distance from the columella as point [illegible] A and C is the same as that measured for [illegible] nce from the ala as X is on the normal side Distance A′ and C″ is equal to A and C

B, C′ is the point on the vermilion-cutaneous border on the lateral side of the cleft at the site at which the vermilion edge begins to thin out A line is drawn approximately perpendicular, meeting line A′ C″ at B′ The distance between C′ and B′ should always be equal distance to C″ and B′ The line CB is equal to the line C′ B′.

C, The lines of the incisions are, therefore, line ABC along the vermilion-cutaneous edge of the medial side of the cleft and A B′ C′ along the lateral side of the cleft. These two lines are equal in length

mediately below it. This distance represents the length of the normal lip. With the calipers remaining open at the same distance, a point just inside the ala and medial to it, corresponding to the location of the point in the normal side, is established. (Fig. 171, *A, B, C.*) Allowance for the downward and outward rotation of the ala should be made. The lower point of the calipers is moved laterally until it meets the mucocutaneous edge. This site is marked. A point is next made on the vermilion-cutaneous edge at the place where the lip border begins to thin out as it goes up into the cleft. The distance from here to the line connecting the two previous points is measured and this should be brought up or down on the line until it forms an equilateral triangle, with the lower portion of the line first measured to

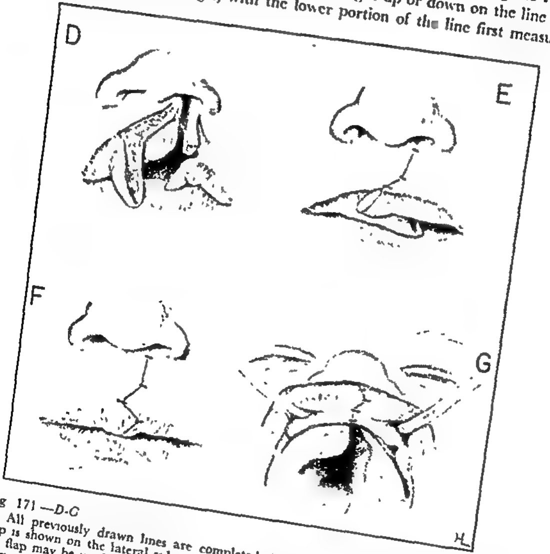

Fig 171 —*D-G*

D, All previously drawn lines are completed through the full thickness of the lip A small flap is shown on the lateral side, this is usually not needed and is amputated. If necessary, this flap may be used to build up the nostril floor.

E, The undersurface of the lip has been sutured with chromic catgut and the outer skin layer has been sutured with interrupted six 0 silk

F, The vermilion edge of the lip is cut in a notched fashion and sutured with interrupted silk sutures

G, The undersurface of the lip showing relaxation incisions following closure.

the mucocutaneous edge The site is marked on the first line The lower part of the original line is now disregarded and the total length of the angular line so formed will be equal to that of the normal side of the lip. The calipers are then moved to the medial side of the cleft and a point is established opposite the base of

the columella, corresponding in location to that taken on the normal side. Attention is called to the fact that the columella may be twisted downward, and allowance should be made for this. The lower point of the calipers is moved medially until it reaches the vermilion-cutaneous edge. It will be noted that this line cuts across the lower part of the lip sulcus. A third point is measured from the point on the vermilion-cutaneous edge upward along the previous line for a distance corresponding to that of the lower angulated portion described on the lateral side of the cleft. If this point can be carried toward the vermilion-cutaneous edge, it will preserve more of the skin in the lower lip.

Following relaxation of the lip, as described, a sharp-pointed knife is carried through the lip at the point in the nostril floor and a through-and-through cut is made along the lines previously marked (Fig. 171, *D*). When the lowest point is reached on both sides, the resulting vermilion flaps are turned outward and closure of the lip is begun (Fig. 171, *E*). The mucosa and muscles are closed with 000 chromic catgut, beginning at the nostril floor and proceeding downward (Fig. 171, *F* and *G*). All sutures are the inverted on-end mattress type. The first suture is most important and should bring the soft tissue beneath the nostril together without tension, establishing a normal height, width, and thickness corresponding to the opposite side. As each suture is taken, the lower part of the lip should be brought together in order to prevent unequal approximation. When the lowest cut edge is reached, the skin sutures are started. A simple mattress suture of six 0 silk is used which includes only the skin. The nostril floor is closed first and then the remainder of the lip is finished. When the skin-vermilion edge is reached, the two vermilion flaps are cut in a tongue-and-groove fashion, producing the desired thickness to the lower lip edge. The medial flap is the best to use as the tongue should fit smoothly into the notched lateral edge. This portion is closed with on-end mattress sutures of six 0 silk to prevent rotation of the edges inwardly. If there is still some prolapse of the lower cartilage into the nostril, it can be secured in an elevated position with sutures passing from the outer skin through the cartilage along its upper edge. Some operators employ stay sutures though the ala, floor of the nostril, and columella, to relieve tension, but we have never found this necessary.

The technic of the operation for repair of the single cleft lip as done by LeMesurier is as follows (Fig. 172): The normal side of the lip is estimated by taking a point at the floor of the normal nostril with calipers and extending them to the mucocutaneous junction directly below it. The line of the abnormal side of the lip is measured with a point just within the ala on the cleft side corresponding to that of the ala on the normal side and the distance is measured to the mucocutaneous border corresponding to that of the normal lip. The calipers distance is then reduced to two-thirds of its original opening and rotated laterally or medially so that the distance between the distal point of the compass and a line drawn perpendicular to the vermilion-cutaneous border will equal one-third of the length of the normal lip. The point of the calipers pierces the skin to establish this definite side. Where the vermilion border of the lip begins to thin out, a line is drawn from the mucocutaneous junction perpendicular to that of the first line. The point at which this line ends on the first line should not be more than one-third the distance of the normal lip from the end of the first line This completes the measurements on the lateral side of the lip. On the medial side a point is taken at the base of the columella

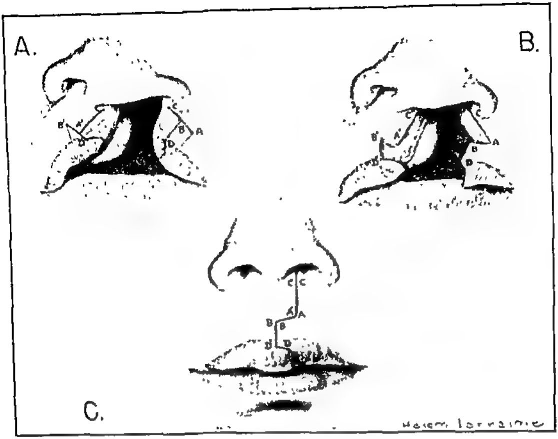

Fig. 172 —LeMesurier's technic for repair of the unilateral harelip

A, A'C' is measured from the base of the columella to just above the vermilion-cutaneous border to the medial cleft This should be two-thirds of the length of the normal lip B'D' is a line drawn perpendicular to A'C', D' being slightly over the vermilion-cutaneous edge with B'A' approximately one-half the distance between A'C'. Line CA is equal to C'A' and and is drawn from the inner side of the base of the ala to a point above the vermilion-cutaneous edge of the lip corresponding to one-half the distance between A and C. Line DB is drawn approximately perpendicular to CA and extends over the vermilion-cutaneous border of the lip The tongue flap is outlined on the medial surface of the vermilion edge of the lip and a corresponding notch is outlined on the lateral vermilion edge of the lip. The distance of B' and A above the vermilion-cutaneous edge is the same. (Fine straight line.)

B, Incisions through the full thickness of the lip are made along the previously measured lines

C, Completion of the operation with all points on each side coinciding

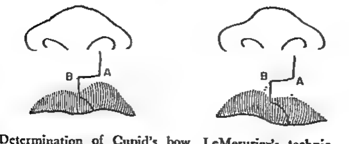

Fig 173 —Determination of Cupid's bow, LeMesurier's technic. The perpendicular height of B and A from the vermilion-cutaneous edge denotes the respective height of the two sides of the Cupid's bow.

corresponding to that which was taken on the normal side of the lip. With the calipers set to equal two-thirds of the normal lip length, the distal point is rotated until it is just above the mucocutaneous junction. *(Fig. 172, A, B,* and *C.)* With the calipers reduced to one-third the length of the normal lip, a second line is drawn perpendicular to the first at its distal end extending from the mucocutaneous junction upward and outward across the mid portion of the lip. These lines should be clearly outlined by marking with gentian violet or by lightly incising with a sharp knife. The lip is then undermined by incisions made in the buccal alveolar fold, and dissection includes the muscles, the soft tissue attachments over the maxillary bone, the frontal process on the lateral sides and beneath the columella and ala on the medial side. If it is an incomplete harelip, the cleft should be completed into the floor of the nostril at this time. With a sharp-pointed blade, the incision is carried through the entire thickness of the lip along the lines previously measured. When the mucocutaneous border is reached, the incision is then stopped and the flaps so formed are retracted laterally. With small sharp pointed scissors, the skin over the lower lateral cartilage is undermined by passing the scissors beneath the exposed area of the ala upward and over the cartilage and across the midline to the opposite side. If there is an excessive amount of mucous membrane present between the lower edge of the upper lateral cartilage and upper edge of the upper lateral cartilage, as is evidenced by buckling of the lower cartilage when the nostril floor is closed, this should be removed by a triangular incision which is closed with fine six 0 silk sutures. The soft tissues beneath the floor of the nostril are closed by interrupted 000 chromic catgut. These sutures are used to close the entire mucous membrane beneath the lip until the vermilion edge flaps are reached. This skin is closed with interrupted six 0 silk, care being taken to approximate all points neatly and accurately. It will be found in occasional cases that there is slight fullness of the lower one-third of the lip on the medial side. If this is true, the excessive amount of skin in this area can be excised to correspond accurately with that on the opposite side. Following this closure, the vermilion flaps are cut in a tongue-and-groove fashion. The medial flap, having a more normal fullness, is used as the tongue, and a notch made into the lateral mucosal flap to correspond with it. These should be made to fit accurately and give the desired thickness to the edge of the lip and are sutured together with interrupted six 0 silk sutures. It will be noted that this procedure gives ample fullness to the lower third of the lip and will also produce a Cupid's bow which gives a very desirable cosmetic appearance. A note concerning the formation of the Cupid's bow by this technic should be given at this time. The perpendicular distance between the end of the original line on the lateral side of the lip and the lateral end of the second line on the medial side of the lip to the mucocutaneous junction on their respective sides determine the height of the Cupid's bow and should always be equal in length. The longer the distance, the flatter the bow, the shorter the distance, the higher the bow. The accompanying diagram is used to explain these points more clearly (Fig. 173).

REPAIR OF DOUBLE HARELIP

The present methods of repairing double harelips are satisfactory but leave much to be desired in cosmetic appearance. The one described here is the author's modification of the technic described by Federspiel (Fig. 174). The distance be-

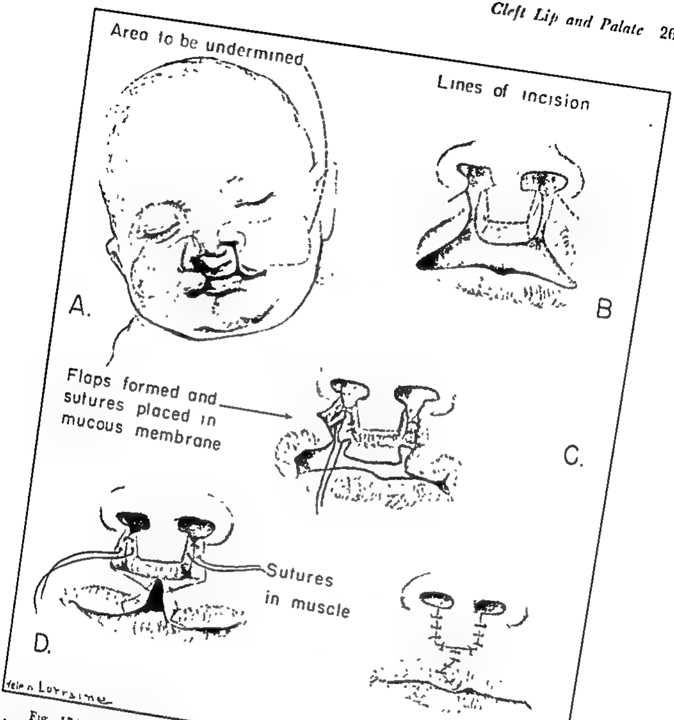

Fig 174.—Modified Federspiel repair of double harelip. *A*, Area over each maxilla which should be undermined by relaxation incisions in the buccal alveolar sulcus (dotted lines) *B*, The prolabium is incised along previously measured lines which should include the maximum amount of skin area which can be utilized Lateral incisions extend from the base of the ala on each side and should equal the lateral perpendicular lines on the prolabium. *C*, The lip has been incised along previously measured lines and the mucous membrane of the prolabium has been dissected backward and is sutured to the lateral side of the cut edge of the lip with interrupted mattress sutures of chromic catgut *D*, Subcutaneous tissue and muscles are closed with interrupted 000 chromic catgut, although this suture is not always necessary. The lateral flaps are brought together beneath the posterior edge of the prolabium and the excessive amount is excised in a tongue and groove fashion. *E*, The skin and vermilion edges of the lip are closed with interrupted six 0 silk.

tween the base of the columella on one side and the mucocutaneous border imm-- ately below it on the prolabium is measured. Both points are definitely determ by piercing the skin with calipers. The opposite side is measured in like ma and at the same distance. With the calipers at the same measurements a poi taken just within the ala on the lateral side of the lip and this is pointed down and slightly outward from the mucocutaneous edge. This distance between lower end of the caliper and the mucocutaneous junction of the cleft is appı mately one-half that of the measured distance of the calipers. The point is e lished by piercing the skin with the instrument. The distance between the d point and the mucocutaneous edge of the cleft will determine the area of which is to be placed beneath the lower edge of the prolabium, thus accountin approximately the area of skin of the lower third of the lip. If the prolabiu very short, it may be desirable to increase the amount of skin in the lower por of the lip and this can be done by moving the distal point on the lateral side la ally, giving more room between it and the mucocutaneous edge. The incision in prolabium is begun by incising the skin along the line between the two point each side previously measured. The two lowermost points are connected by inci the lower edge of the lip along the mucocutaneous junction. This incision is usu curved to preserve as much skin as is available in the lower part of the prolabi These incisions do not include the full thickness mucous membrane edge and a being made the mucous membrane is everted over the premaxillary process and tured to it with six 0 silk at each of its four corners This mucous membrane p vides the necessary mucosal edge to the undersurface of the repaired lip which m be preserved. The lateral sides of the lip are extensively undermined by incisi placed within the buccal alveolar fold and are carried down to the bone laterally a distance of approximately 2.5 to 3 cm. The muscles and soft tissue are dissec upward to the infraorbital ridge and medially over the frontal process of the ma lary bones. This relaxation usually is sufficient to allow the lip to be brought gether to the prolabium without tension. When increased relaxation has to made, perpendicular incisions extending downward toward the lip edge can made on the mucous membrane approximately 1 cm. from the terminal part of original undermining incision. Frequently, because of the extreme protrusion the premaxilla, it is necessary to bring this backward and downward to gain a s isfactory approximation of the entire lip. This is done by incising the mucous me brane overlying the septum approximately 2 cm from the posterior tip of the p maxillary process. This is dissected away from the bone, and a triangular piece resected with the base along the lower edge, its length being dependent upon th amount necessary to produce the desired recession. This mucosa is closed over t defect. Incisions are next made in the lateral portions of the lip cleft along t line previously described, beginning at the ala points and extending downward the distal point. This incision is made, using a sharp-pointed blade, and i cludes the entire thickness of the lip The flaps of skin and mucous membrane a retracted downward, exposing the raw surface, which is united to the correspon ing raw surface of the prolabium by interrupted mattress sutures of 000 chrom catgut, beginning at the nostril floor and extending down until the entire length the prolabium has been reached The lateral flaps are brought beneath the low

edge of the prolabium and the excessive amount is removed from each side to produce closure of these flaps in the midline. The undersurfaces of these flaps are sutured to the mucous membrane along the lower edge of the prolabium with interrupted 000 chromic catgut and to each other in the midline with the same type of suture. The skin incisions are closed with interrupted mattress sutures of six 0 silk. It will be found almost invariably that the lip has the desired length and fullness. However, the nose will inevitably be flat and the nostril floors widened. Obviously, this is because of a shortened columella, and no attempt should be made to lengthen this or to rearrange the lower lateral cartilages at the initial operation.

Postoperative care of these patients is extremely important, if good results are to be obtained. Following the operation, no dressing is applied, but a Logan lip clamp is strapped across the upper lip to relieve tension and to prevent direct trauma to the operative site. The child should be watched for postoperative bleeding and asphyxiation from aspiration of mucus or blood. If reaction from the anesthetic is uneventful and there are no complications, the first feeding may be given at the end of three hours. Feeding should be given with an Asepto syringe, as a nursing bottle produces undue exercise of the lip and will increase the amount of edema. The hands should be restrained. The suture line should be cleansed with 50 per cent hydrogen peroxide every hour for the first twelve hours following operation and every four hours after that until the sutures are removed. This care is imperative or else the wound will become grossly contaminated with mucous discharge from the nostril which produces maceration of the tissue and invites infection. The silk sutures should be removed at the end of three to four days, depending entirely upon the amount of edema present and the degree of wound healing. The lip guard is removed at the end of seven days. At the end of two weeks light massage of the lip with cocoa butter will hasten the absorption of any areas of induration and aid in making the scar more pliable. Bottle feedings may be resumed at the end of two weeks. The antibiotics are not used unless definitely indicated.

REPAIR OF CLEFT PALATE

Cleft palates can be placed into four groups, as described by Pick: incomplete cleft of the soft palate, clefts of the soft and bony palate, cleft of the palate with cleft of the alveolar process, and bilateral palate. It should be the aim of this repair to secure a palate that is adequate in length and of good muscular function so that in speech the palate will meet the posterior pharyngeal wall, thus closing off the nasal passages and giving a normal tone to the voice. If the operation does not meet the above requirements, even though the palate is closed completely, the results may be considered as unsatisfactory The operation of choice in most clefts, regardless of the type, is that of von Langenbeck, which, with a slight modification, is as follows: The hamulus is palpated as it projects from the lateral inferior border of the palatine bone With a sharp knife, an incision is made from its tip extending up to the posterior edge of the alveolar process and around this and extending anteriorly on the medial side for a distance of approximately 1 to 2.5 cm. With periosteal elevators which are inserted through the anterior portion of the incision, the mucous membrane and periosteum are dissected off the bony palate. Care is taken to

preserve the posterior palatine artery as it comes out of the palatine bone and enters the mucous membrane approximately 0.5 cm. above the posterior edge of the palatine bone and 0.5 cm. medial to the posterior portion of the alveolar process. The mucous membrane is elevated on the medial side at the cleft edge and the attachment of the palatine muscles to the bone is exposed. These are separated from the bone by sharp dissection. Through the relaxation incision the hamulus and its attachments are viewed. The attachments are separated from the hamulus by sharp dissection, and following this the entire palate can be moved medially without tension. The membrane covering the posterior cleft edge of the palate is incised, beginning at the anterior border and extending through the tip of the uvula. The edges are dissected open, exposing the underlying musculature. (Fig. 175.) Closure is begun by suturing the muscles and mucous membrane of the nasal side of the palate with interrupted mattress sutures of 000 chromic catgut, after which the oral side of the entire palate is closed with on-end mattress sutures of four 0 silk. The relaxation incisions are left open and all bleeding is controlled by packing these incisions with dry gauze.

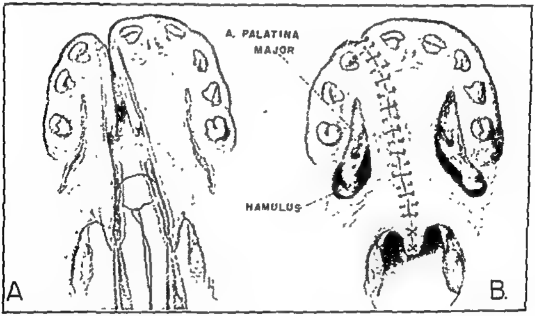

Fig. 175 —*A*, Relaxation incisions are made along the inner sides of the posterior portion of the alveolar ridge and continued behind the posterior edge. The muscles of the soft palate are divided from the posterior edge of the bony palate and also dissected from the hamulus The muscles and mucous membrane of the nasal surface are sutured with interrupted 000 chromic catgut *B*, The palatina major artery can be seen extending into the lateral flaps. *The oral mucous membrane is closed with interrupted mattress sutures of silk.*

There are other types of repair which are advantageous in certain selected cases. The von Langenbeck has the disadvantage of not always giving the palate a normal length. In clefts of the soft palate the operation of Dorrance (Fig. 176) affords a better result in cases in which shortening of the palate would be expected by using the von Langenbeck method. This technic is carried out by making a horseshoe-shaped incision, beginning at the posterior border of the alveolar ridge and continuing around its medial border to the opposite side. The mucosa and periosteum are dissected up as a flap off the palatine bone. The muscles are separated from the posterior edges of the bone and the entire palate is pushed back-

ward. (Fig. 176.) The anterior edge of the flap is sutured to the incised mucosa on the nasal side of the palatine bones. This produces increased length of the palate. The cleft is closed by denuding the mucosa over the muscles of the cleft and suturing the muscles and mucosa of the nasal side with interrupted 000 chromic catgut and the mucosa on the oral side with interrupted on-end sutures of four 0 silk. The denuded areas of bone in the anterior part of the palate readily heal by scar tissue. Some surgeons prefer to graft the underside of the mucous membrane

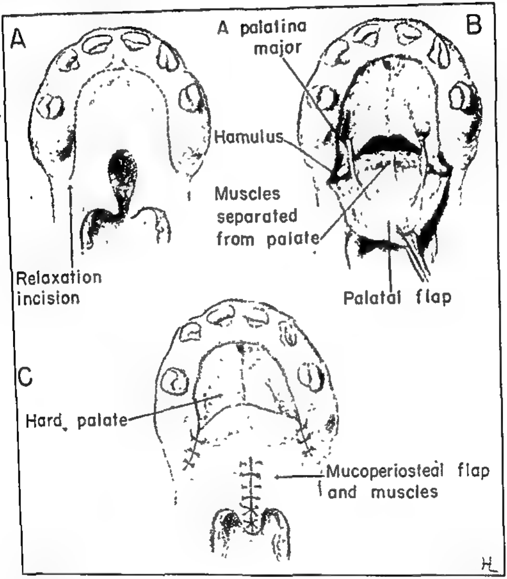

Fig. 176.—Dorrance "push back" operation for closure of cleft of soft palate. *A*, Horseshoe-shaped incision extending around inner margin of alveolar process *B*, Mucoperiosteal flap elevated and muscles of the soft palate dissected from the posterior edge of the bony palate. *C*, The mucoperiosteal flaps sutured to the adjacent mucous membrane of the alveolar process and to the nasal mucous membrane covering the hard palate. The edges of the cleft have been denuded and closed with interrupted silk sutures.

flap with a split thickness skin graft before the "push-back" operation is carried out The reason for this procedure is to prevent scar tissue contraction of the raw surface of the exposed mucoperiosteal flap.

In repair of cleft palates extending through the alveolar process, it is sometimes impossible to close the opening existing between the floor of the nostril and

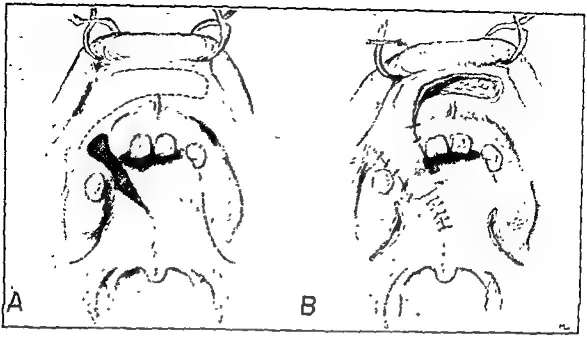

Fig. 177.—*A* and *B*, Lip flap for repair of defect in the alveolar process in the anterior portion of the hard palate.

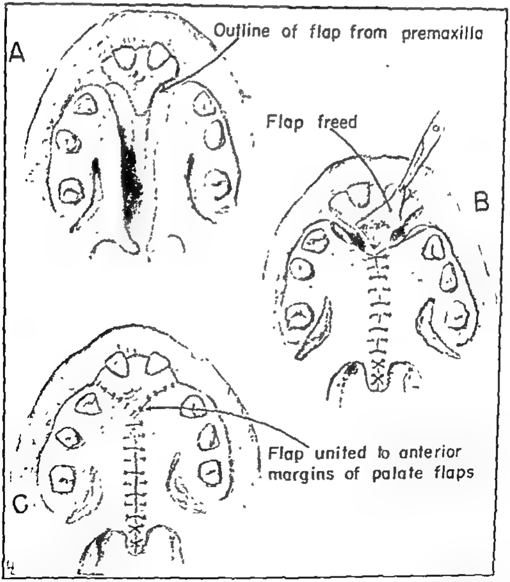

Fig 178 —*A*, Double cleft of the palate closed by relaxation incision along the posterior medial border of the alveolar process *B*, Shows closure of main portion of palate. *C*, All mucous membrane edges are closed with interrupted silk sutures.

the alveolar process with the von Langenbeck procedure. When this occurs, it can be corrected by making an incision in the buccal alveolar fold on both sides of the cleft and outlining a flap on the buccal side which will be sufficiently long and broad to meet the edge of the anterior palate by carrying it through the defect in the alveolar ridge. This flap is dissected up and should include a small portion of the muscle of the upper lip. It is carried through the defect and sutured to the

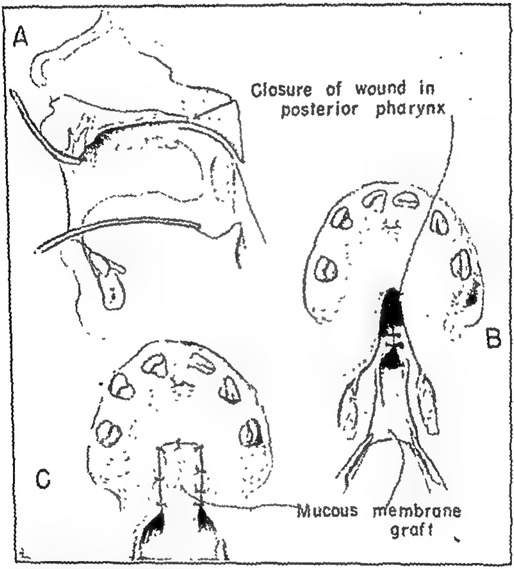

Fig 179.—Palatopharyngoplasty. *A*, The posterior wall of the pharynx for its entire width is dissected up. The flap is swung anteriorly and sutured to the posterior denuded edge of the soft palate with interrupted silk sutures. *B*, Closure of the lateral edges of the pharyngeal wall with interrupted chromic catgut sutures. *C*, The pharyngeal flap is sutured to the soft palate. Air can pass from the nasal cavity along the lateral pharyngeal spaces.

mucosa of the anterior palate at the edge of the cleft with interrupted four 0 silk. (Fig. 177.) The latter procedure may be done at the time of the initial operation or may be delayed until another time to allow for decrease of the size of the cleft of the alveolar process. Bilateral cleft palates likewise give rise to the major problem of the fixation of the premaxillary process and closure of the two defects of the alveolar ridge. If the von Langenbeck closure is used, the mucosa is dissected from the posterior border of the premaxillary process by an incision around its edge.

Following its dissection upward from the bone, it can be sutured to the anterior edge of the mucoperiosteal flap on each side after their dissection from the anterior surface of the hard palate. If this does not permit closure and the opening persists between the alveolar process on each side of the premaxillary bone, these can be closed by dissecting up the *mucomuscular flaps from the undersurface of the lip* as described above. If the premaxilla is not closed but is in contact with the edges of the alveolar ridge on each side, simple removal of the mucosa of the edge of the premaxilla and alveolar process will frequently suffice to produce a fibrous union (Fig 178.)

Postoperatively it is important that these patients be fed with a spoon or glass and not be permitted to nurse a bottle. The hands should be restrained to prevent sucking the fingers and the placing of objects into the mouth by the patient. Penicillin is given routinely. Liquid feedings are given for the first six days, and afterward soft foods may be taken. No local treatment is necessary to the operative site. The silk sutures are removed in three weeks. The majority of these patients do not get full use of the musculature of the palate for approximately six to eight months. Therefore, immediaate change to normal speech may not be noticed.

As has been stated, the most frequent complication is shortening of the palate, resulting in failure of closure of the space between the oral and nasal cavities This can be *corrected surgically by the use of a pharyngeal flap sutured to the posterior* edge of the palate (Fig. 179). This technic consists of incising the posterior pharyngeal wall, beginning at the level of the lower edge of the posterior tonsillar pillars and extending upward to a point 1.5 to 2 cm. above the level of the posterior edge of the palate. The upper ends of the incisions are connected by a transverse incision extending through the mucosa and muscle. The entire flap is elevated and sutured with 000 silk to the posterior edge of the palate following removal of the mucous membrane along its posterior border. Breathing through the nose in these cases is accomplished by air passing down the lateral apertures on each side of the pharyngeal flap.

REPAIR OF POSTOPERATIVE DEFECTS

Because of the influence of growth of the face, nose, and upper lip, even the best repair will frequently demand operations to correct defects that occur later in life. The most common defects are those occurring in the nostril on the involved side. The most frequent of these is flaring of the nostril with prolapse of the tip of the nose, causing the longest plane of the nostril opening to extend transversely rather than longitudinally. The cause of this deformity is usually twofold: First, the pull of the muscles of the face drags the ala laterally and downward because of the insecure support of the nostril floor Second, the lateral wing of the lower lateral cartilage is attached lower on its ala side than in the normal nostril This causes the tip of the nose to become flattened. This condition may be corrected by dissecting the entire lateral wing of the lower lateral cartilage from the overlying structures and rotating it medially and suturing it at its normal height to the apex of the normal cartilage on the opposite side (Fig 180) In occasional cases where there is a prolapse of the affected side of the nose producing a drooping of the tip, the above operations for elevation of the tip of the nose may not suffice because there is an ex-

cessive amount of skin over this side of the tip. This is particularly true in children who have had the deformity for a number of years. In order to produce a normal-appearing tip on this side, one has to resect the excessive skin. This is done through an elliptical incision beginning at the tip of the nose in the midline slightly to the affected side, extending up over the lower outer edge of the lower lateral cartilage. The amount of skin removed, of course, should be enough to elevate the deformed side to a level with that of the normal side. The skin is closed with interrupted six 0 silk sutures. The greatest objection to this type of procedure is that it leaves the patient with a fine scar on the outside of the nose; however, this is less noticeable than a prolongation of the tip of the deformed side.

The flare of the nostril is corrected by removing a wedge of skin and soft tissue from the nostril floor and narrowing the floor in this manner, bringing the soft tissues under the ala and suturing them to those beneath the base of the columella to improve the support in this area.

A.

B.

Fig 180—Rotation of flattened lower lateral cartilage to its normal height, correcting the excessive unilateral widening of the nostril.

SECONDARY REPAIR OF POSTOPERATIVE PALATE DEFECTS

The most common palate defect, other than shortening of the palate, is a perforation. This may vary in size and often is large enough to permit the passage of food and liquid into the nasal cavity. Speech is affected also, which makes it all the more essential that the defects be closed. Small defects ranging up to 1 cm. in diameter may be closed by mucosal flaps dissected up from the adjacent palate area The base of these flaps should always be directed toward the side of the palate that affords the best blood supply. The edges of the opening are denuded of mucosa. The outline of the flap is made slightly larger than the area of the defect, with its base slightly wider than the width of the tip. Following its elevation, it is swung over the opening and sutured to the surrounding mucosa with interrupted four 0 silk. (Figs. 181 and 182.) The flap bed is left open and unprotected and heals with scar tissue. Defects larger than 1 cm. are best closed by incisions made along the medial edge of the alveolar ridge opposite the opening, and the mucosa and periosteum are completely elevated so that the area around the perforation is free from tension. The edges of the opening are then denuded. The two palatine flaps are brought together and sutured with interrupted four 0 silk. (Fig. 183.) Openings which do not permit either of the above methods because of insufficient mucosa or because of their extreme size can be closed by mucosal flaps from the cheeks. This is carried out by dissecting out a pedicle flap 0.25 cm. larger in its periphery than that of the defect, swinging it over the alveolar ridge and suturing it to the denuded edges of the opening with interrupted silk. These are left in place for two weeks until healing is assured. The pedicle is then divided and returned to its original location The remaining edge of the flap on the palate is sutured with interrupted four 0 silk to the normal mucosa. Extremely large openings involving more

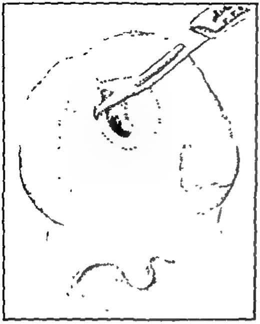

Fig. 181.

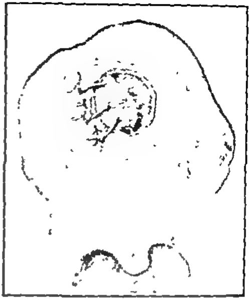

Fig. 182.

Fig. 181.—Incisions for operation used in closure of a small cleft in the anterior palate.
Fig. 182.—The operation completed.

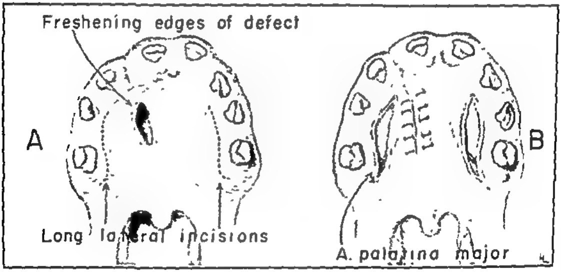

Fig 183.—*A*, Closure of large perforations of the palate. *B*, The edges of the perforation are closed with interrupted mattress sutures of silk.

than half of the palate, in which mucosal flaps are not advisable because of lack of normal palatine tissue, are best covered by a prosthetic appliance. In the past, tube flaps from the arm or neck have been used for this correction. They have very little to offer, however, except as a diaphragm, and a dental prosthesis is considered more advisable.

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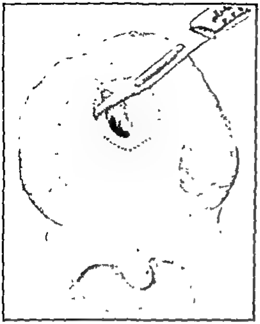

Fig. 181.

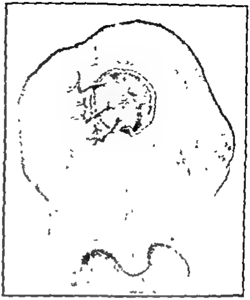

Fig. 182.

Fig 181 —Incisions for operation used in closure of a small cleft in the anterior palate. Fig. 182.—The operation completed.

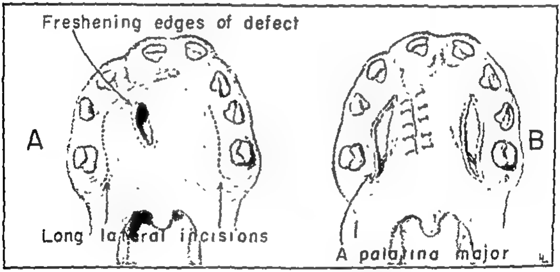

Fig 183 —*A*, Closure of large perforations of the palate. *B*, The edges of the perforation are closed with interrupted mattress sutures of silk.

than half of the palate, in which mucosal flaps are not advisable because of lack of normal palatine tissue, are best covered by a prosthetic appliance. In the past, tube flaps from the arm or neck have been used for this correction. They have very little to offer, however, except as a diaphragm, and a dental prosthesis is considered more advisable.

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CHAPTER 20

PLASTIC REPAIR OF ACQUIRED DEFECTS OF LIPS, CHEEKS, EYELIDS, AND FOREHEAD

LEROY SMITH

THE LIPS

Operations for congenital deformities of the lips have already been considered. Plastic operations on the lip may also be necessary for deformities acquired either from accidental trauma or from removal of a malignant growth. Operations for cancer should be planned primarily with a view to curing the cancer, and the cosmetic effect should be a secondary consideration. Halsted has observed that if the surgeon who operates for cancer did not attempt to close the defect, but left this for some one else, all temptation to leave conditions favorable for a closure of the wound would be removed, more malignancies would be cured, and plastic operations after removal of cancer would fall into the same general category as accidental trauma

The upper lip is rarely the site of malignant disease, whereas cancer of the lower lip is common. Reconstruction of the upper lip, aside from congenital deformity, is required usually on account of accidental trauma. A satisfactory operation for reconstruction of the upper lip is that in which flaps are taken on each side, either extending upward with the base downward, according to the method of Denonvilliers, or extending downward with the base upward according to the method of Sedillot. The method of Denonvilliers consists of two vertical flaps that are made through the full thickness of the cheek with the pedicle below (Figs. 184 and 185). The external incision extends from the lower border of the jaw to the level of the ala of the nose, and the internal border of the flap is the margin of the defect in the upper lip. A transverse cut is made to loosen the flap, which is turned down and sutured in the midline beneath the nodes. The mucous membrane lining the flaps must be arranged to form the vermilion border. The flap contains the whole thickness of the cheek. In the operation of Sedillot the flaps are reversed, taken with the base above. These flaps are turned upward and inward and the vermilion border is made along the lower margins of the flaps (Fig. 186).

The upper lip may be constructed from hair-bearing tissue by taking a long flap from the temporal region which includes the scalp and turning it down A similar flap is taken from each side and the pedicle is cut after the local nutrition seems to make the flap viable

In asymmetrical deformities of the upper lip the general principles of plastic work, which have already been discussed, can be applied. If there is too great contraction of the upper lip, the method of Abbé may be utilized and a pedicle flap turned up from the lower lip. According to this method, the defect in the upper lip is prepared and a flap from the lower lip with the pedicle on one side is turned up

and sutured in position (Figs. 187 and 188). The lips are held together with sutures and the patient is fed through a tube for twelve or fourteen days, when the pedicle is cut (Fig. 189). This is a very valuable method, particularly when the lower lip is somewhat redundant. Gurdon Buck's operation involves the same principles, but a more extensive flap is taken, including probably a third or even half of the lower lip as well as the angle of the mouth (Figs. 190 and 191).

Fig. 184.—Lines of incision for repair of upper lip by method of Denonvilliers.

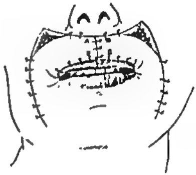

Fig. 185.—Operation of Denonvilliers completed.

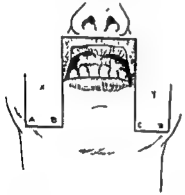

Fig. 186.—Operation of Sedillot for repair of the upper lip.

Fig. 187.—Lines of incision for repair of defect in upper lip by method of Abbé.

Fig. 188.—The flap from the lower lip has been turned into the defect in the upper lip, according to Abbé. The flap is kept in this position for about two weeks, when the pedicle is cut.

Fig. 189.—The pedicle has been cut, and the operation of Abbé completed.

In any operation upon the lip, particularly upon the upper lip, it is necessary that the internal surface have a satisfactory lining, preferably of mucosa. If this is not possible, a lining may be made with skin by a flap turned up from the neck. If the raw surface left within the mouth is very extensive, contraction is sure to occur

and so much scar tissue may involve the flap that a secondary operation will be necessary later. If possible, a flap of mucosa from the tissues in the neighborhood should be utilized to line the skin flaps.

The lower lip may be reconstructed from flaps in its neighborhood or from a distance. The lower lip is frequently the site of cancer and reconstructions are often necessitated by operations for this disease. The simplest method of removing cancer and reconstructing the lip after its removal is by the V-shaped excision. If the cancer is extensive this method cannot be used, but in many early cases of malignancy the V-shaped excision is entirely satisfactory. Care is taken to keep a safe distance from the margins of the growth. The incision is so made that the V will be

Fig. 190.—Lines of incision for the operation of Gurdon Buck in repair of the upper lip

Fig. 191.—Operation of Gurdon Buck completed.

Fig 192 —V-shaped excision for cancer of the lower lip

Fig 193.—V-shaped incision closed with sutures

deep and not too shallow (Figs. 192 and 193). This not only results in a more extensive removal of tissue, but at the same time the closure of the wound is more satisfactory. The incisions are made through the skin and down to the mucosa. Two through-and-through sutures of silk are inserted, one just below the vermilion border and one farther down. The loops of the suture are held out of the way, the mucosa is quickly cut, and the lip is approximated In this way not only is bleeding lessened, as it can be controlled satisfactorily by the sutures, but there is a minimum exposure of the wounded surfaces to the secretions of the mouth The rest of the incision is accurately approximated with interrupted sutures of silk or horsehair for the skin, and silk for the mucosa By making a transverse incision at each corner of the mouth, the V-shaped incision can be applied in a much larger number of cases, and this may be combined with the Burow-Stewart principle of excising a

triangle of tissue down to the mucosa just above the angle of the mouth on each side. In this manner a considerable portion of the lower lip can be removed with comparatively little deformity.

In extensive cancer of the lower lip the operation of Stewart is excellent. The first incision is just below the jaw from one angle of the lower jaw to the other. The skin and platysma are dissected down and a block dissection is made of the upper neck, including both submaxillary glands. This dissection is made from below upward. Incisions are then made on each side of the cancer at a sufficient distance from the growth and are carried down to the original transverse incision. The lateral flaps are freely dissected from the jaw, the incision being kept close to the skin at the lower part to avoid the lymphatics. The cancer and the tissues of the block dissection of the neck are removed in one mass. If most of the lower lip is removed with the cancer, the mouth is broadened by a straight incision outward from each angle of the mouth, carried down to, but not through, the mucosa. A triangular incision is then made in the cheek just above the angle of the mouth. This triangular incision goes down to the mucosa, but not through it. The mucosa is cut a half inch above the level of the lower lip and turned down to make a vermilion border. The lateral flaps are brought forward and sutured together in the midline, the new chin also being sutured to the soft tissues on the jaw to protect the neck wound from the contents of the mouth.

The lower lip may also be reconstructed by turning down flaps with the base below, the flaps so placed that the incisions to close them will lie in the fold running from the outer portion of the ala of the nose to the corner of the mouth (Figs. 194 and 195).

The operation of Abbe or of Gurdon Buck for reconstruction of the upper lip can be reversed for the lower lip (Figs. 196 and 197). The principle of Dieffenbach can be applied here in securing two flaps, one from each side of the defect, and bringing them together in the midline (Figs 198 and 199). This procedure leaves a triangular raw surface at the outer portion of each flap, which can be taken up by sliding further flaps, by undermining and suturing or by grafting skin.

In complete absence of the lip a visor of skin may be turned up from the neck just below the chin and sutured in position (Fig. 200). This, however, is likely to contract, though the tendency may be lessened by nailing the flap to the jaw with small wire nails or brads and holding it in this position until it becomes firmly fixed. The operations of Sedillot may also be used in some cases (Figs. 201, 202, and 203).

In extensive burns where the mucosa of the lip is not affected but where contraction is marked and scar tissue so abundant that no flap can be secured in the neighborhood, the method of obtaining a flap from the arm offers a solution of the problem. The flap is best taken with its base near the axilla, and the incisions for it are carried around the arm so that the apex of the flap lies in front and a little to the outer side of the elbow. Such a flap is well nourished, as it contains vessels that run in the general direction of the blood supply of this part and there is very little twist in the pedicle. If a flap is taken with the apex toward the axilla and base farther down the arm, the nutrition is somewhat imperiled and a larger raw surface of the arm is kept in contact with the face than would be with a flap having its base toward the axilla The mouth is first prepared for the reception of the flap by thorough excision of its scar tissue. The flap which will furnish ample

skin covering is dissected with some underlying fat and sutured in position with interrupted sutures of fine silk. The raw surface of the arm is covered with rubber protective or oiled silk. The arm is put over the head after covering it with a flannel bandage and is fastened in position by plaster of Paris bandages which run over the head. The hair is protected by a cloth or rubber cap. It is unnecessary,

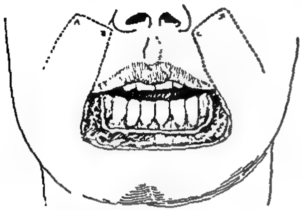

Fig. 194.—Lines of incision for operation of Bruns in repair of lower lip.

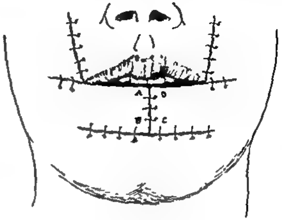

Fig. 195.—Operation of Bruns completed.

Fig. 196.—Lines of incision for operation of Estlander for repair of lower lip.

Fig. 197.—Operation of Estlander completed.

Fig. 198.—Lines of incision for operation of Dieffenbach in repair of lower lip.

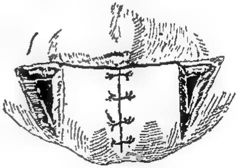

Fig. 199.—Operation of Dieffenbach completed.

as a rule, to put plaster of Paris around the neck, which makes dressing the wound difficult. At the end of two weeks the pedicle is cut. The flap is undisturbed for about a month after the pedicle is cut and is then refashioned and smoothed to fit accurately with the adjoining tissues. Particular care is paid to the junction of the flap with the skin of the face in order that there may be no depression along the line of union.

In young patients the nerve supply to these flaps develops rapidly and, within two months from the time the transplant has been made, sensation of pain and touch in the transplanted flap becomes perceptible.

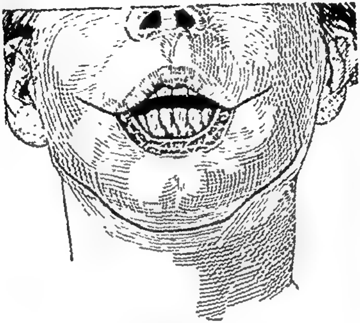

Fig. 200.—Lines of incision for "visor" operation in repair of lower lip, according to Viguerte-Morgan.

Fig. 201.—Lines of incision for operation of Sedillot in repair of the lower lip.

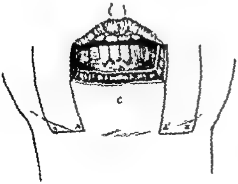

Fig. 202.

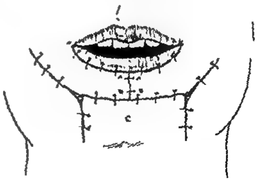

Fig. 203

Fig 202.—Lines of incision for second method of Sedillot in repair of the lower lip.
Fig. 203—Second method of Sedillot completed.

In a lesion of the angle of the mouth in which both lips are affected, the operation of Montet is applicable. He uses two quadrangular flaps, one from the cheek and the other from the chin, with the base of each outward. The margins

Fig. 204.—Lines of incision for operation of Montet in repair of angle of the mouth

Fig. 205.—Lines of incision for the operation of Szymanowski for repair of the angle of the mouth.

Fig. 206.—Operation of Szymanowski completed.

Fig. 207.—Lines of incision for correction of downward contraction of the angle of the mouth

Fig. 208.—Completion of operation for correction of downward displacement of angle of the mouth.

Fig. 209.—Lines of incision for operation of Schulten for repair of mucosa of lower lip

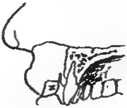

Fig. 210.—Section showing location of flap taken from the upper lip

Fig. 211.—The flap, according to Schulten, has been sutured into position. The pedicles are cut ten days or two weeks later.

of the flap, which are to form the edge of the lip, are lined with mucosa (Fig. 204). If the corner of the mouth is drawn upward, it may be corrected by Szymanowski's operation in which a triangular flap is made with the base downward and the apex external to the ala of the nose (Figs. 205 and 206). This flap is turned into an incision just above the mucous border of the upper lip and lowers the outer angle of the mouth. The method may also be used when the angle of the mouth is depressed. Here a triangular flap is made which includes the depressed angle of the mouth and this is transferred into a horizontal external cut in the cheek (Figs. 207 and 208).

The vermilion border of the lip can be restored by flaps of mucosa from within the mouth. These are sometimes taken from the inner sides of the upper lip, turned down like a visor after the method of Schulten (Figs. 209, 210, and 211), or if all of the vermilion border has not been destroyed, the remaining portion can be dissected free as a flap and stretched to cover the defect (Figs. 212 and 213).

Fig. 212.—Lines of incision for repair of mucosa of lower lip according to the method of Nélaton and Ombredanne.

Fig. 213.—Operation of Nélaton and Ombredanne completed.

Fig. 214.—Lines of incision for reconstruction of vermilion border of the lower lip. Tissues from *A* to *B* should be excised and the flap indicated by the lines of incision pulled down. This is the operation of Tripier.

Fig. 215.—The vermilion border of the lower lip reconstructed according to the method of Tripier.

In protrusion of the lower lip, when the mucosa is excessive an oval section may be taken from the mucosa near the point where it is reflected from the inferior maxillary bone, and the wound sutured. This procedure will remove the redundancy and leave no external scar. Contraction of the mouth is dealt with on the general principles of plastic surgery. Excision of the scar tissue, the mucosa being reserved if healthy, is an operation that can be done in most instances. The mucosa is used to form a vermilion border for the newly constructed lip (Figs. 214 and 215). In severe burns both lips may be fashioned from the arm or trunk, as has already been mentioned.

MICROSTOMIA

After burns or ulceration the buccal orifice is narrowed with or without much destruction of the mucous membrane. The occlusion may vary from partial to almost complete atresia. Simple dilatation or division of the angles is not satisfac-

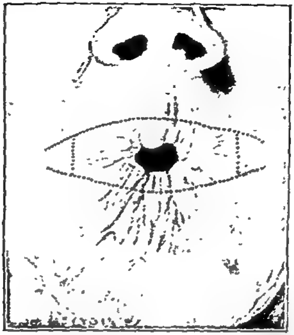

Fig. 216.—Operation for the correction of constriction of the buccal orifice (microstomia) in an eighteen-month-old baby following an iodine burn. Dotted lines indicate incisions which are carried through the skin and scars down to the buccal mucous membrane. (Modified from Ferris Smith and Werneck.)

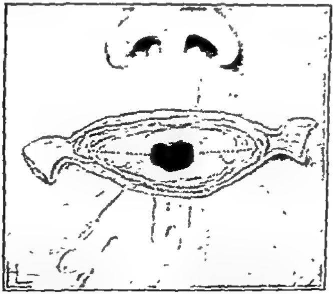

Fig. 217.—Central scar tissue has been removed, mucous membrane mobilized, and lateral skin flaps prepared. Dotted line indicates incision for division of buccal mucous membrane.

tory and will result in recurrence. Werneck's operation consists of a transverse ellipsoid excision of the scar and skin surrounding the contracted buccal opening without incising the mucosa within the mouth. At the same time a small skin flap is left for reconstructing the commissure (Fig. 216). The mucous membrane is

then divided transversely midway between the external incisions from the orifice to the commissure on each side (Fig. 217). The circular scar is removed, and, after the mucous membrane is mobilized from the upper and lower lips, the edges are sutured to the skin. The bilateral skin flaps are folded backward into the angles and sutured to the buccal mucosa to reconstruct the commissures and to prevent further contraction (Fig. 218).

Dieffenbach has employed a similar operation, except that he does not divide the mucosa all the way back to the commissure and he uses a prone Y-shaped incision forming a triangular flap of mucosa at each angle. This flap is carried forward and sutured to the skin. In our experience a combination of Werneck's and Dieffenbach's operations, with square instead of triangular ends for both mucosal and skin flaps, has proved quite satisfactory.

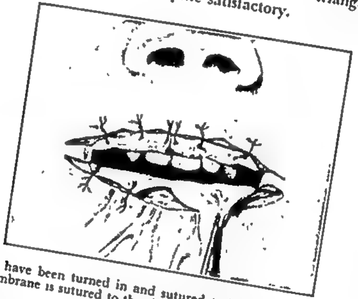

Fig 218.—Skin flaps have been turned in and sutured to line the commissures. The mucous membrane is sutured to the skin margins above and below.

When there is marked destruction of the buccal and labial mucosa, an opening slightly larger than the normal mouth is made and the margins of the scar are sutured. Adhesions are freed and the destroyed mucosa is replaced with a split skin graft applied on a dental compound mold (stent) and buried in the defect by sutures. After a week to ten days, the sutures are removed and the stent is cleansed and replaced The latter procedure is repeated at one- to three-day intervals until satisfactory healing has occurred.

MACROSTOMIA

An abnormally large mouth may occasionally need improvement by shortening the distance between the commissures. Davis has suggested making a V-shaped incision on each side through the entire thickness of the cheek at the desired distance from the mouth angles. The apex of the V is outward and on a level with the commissures. The triangular flap thus formed is shifted toward the midline, and the wound is sutured in the shape of a prone Y. In the more extensive cases he has found it necessary to separate the tissues and suture them in layers.

THE CHEEKS

Defects of the cheek, when not too great, are remedied by flaps from the adjacent tissue. It is necessary to provide an internal lining of either mucosa or

skin. If the defect in the cheek also includes a bony defect in the lower jaw, a flap may be turned up from the neck containing a section of the clavicle; or a piece of rib may be previously transplanted beneath the skin of the neck in such a position that it can be included in the flap and turned into the defect. Great care is taken during the dissection to prevent dislodging the attachments of the bone graft or the section of clavicle. When the clavicle is used, it is sawed to the depth of about 0.5 cm. on each side of the flap before the flap has been completely dissected free, and the bone is severed from the clavicle by a sharp chisel or fine saw. Holes are drilled in the two ends of the bone from the clavicle before it has been severed, the undersurface of the clavicle being protected by a retractor slipped behind it so as to avoid injury to the deeper tissues if the drill should perforate the clavicle (Figs. 144, 145, and 146). It is best to keep the bone firmly fixed to the flap by clamps until it has been secured in the defect. The bone is fastened to the edges of the defect in the jawbone with kangaroo tendon passed through drill holes. The skin flap is sufficiently long to turn over and protect the bone from the mouth.

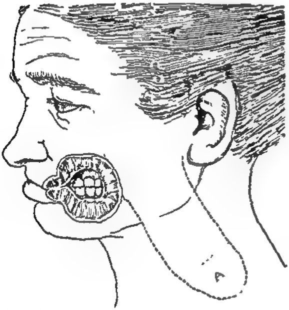

Fig 219.

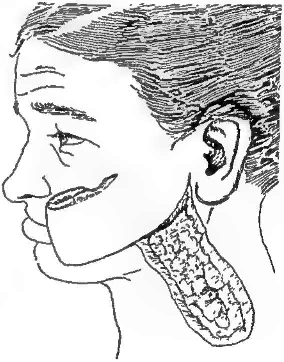

Fig. 220.

Fig 219.—Lines of incision for repair of defect in the cheek and angle of the mouth. The flap is so fashioned that tip *A* is folded over the rest of the flap and turned into the mouth

Fig 220.—The flap indicated in the previous figure has been dissected and placed in the defect

Defects of the cheek that cannot be corrected by sliding flaps from the adjacent tissue may be repaired by turning flaps up from the neck or by securing flaps from the arm or the forehead. If flaps are taken from the neck, they will necessarily be long and should be lined by mucosa or doubled over so as to have an epithelial lining on each side If this is impossible, a flap may be turned into the mouth with the skin side inward and another flap used to cover the raw surface. It is best to separate the flap except at its extremities, "tube" the pedicle, and then in successive stages divide the end opposite the pedicle. This procedure may take several weeks.

It will, however, develop the blood supply and will lessen the possibilities of sloughing. The flap can then be doubled on itself before being transplanted, so that it will be abundantly nourished when it is finally fitted into the cheek (Figs. 219 and 220).

A flap from the forehead may be turned down with the pedicle in the temporal region and the pedicle cut after the flap has taken. This is a much better procedure than transplanting the temporal artery, as was formerly advocated. The local blood supply of the flap may be developed by compressing the pedicle one or two hours a day after the first week, or the pedicle can be severed in successive stages. The great objection to transplantation of the temporal artery alone is that it does not provide a venous return circulation as does a pedicle of skin and subcutaneous tissue.

Willard Bartlett suggests covering the buccal surface of a flap transplanted into the cheek by turning up a flap of mucosa along with some of the tongue. The tongue is cut loose later. In such an instance it is necessary to remove the teeth or at least to protect the mucosa of the transplanted tongue until its pedicle is cut.

FACIAL PARALYSIS

In the problem of restoration of the contour of the face following facial paralysis, improvement has been made in several ways, namely, anastomosis of the hypoglossal nerve to the distal end of the facial nerve, support by facial transplant and

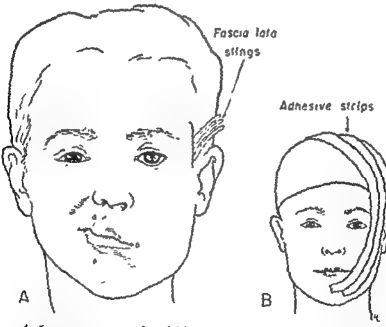

Fig 221 —*A,* Incisions are made within the hairline over the temple area, and a tunnel is made down through the subcutaneous tissue of the cheek past the midline of the upper and lower lip and to the corner of the mouth. Small incisions are made at these points for suturing of graft The fascia lata is passed through the tunnels and sutured to the underlying fascia at each end *B,* Following operation, adhesive strips are passed around the affected cheek, holding the tissues upward into a slightly exaggerated position

by transplantation of the masseter and temporal muscles to the muscles of the face. The most satisfactory restoration seems to be by means of fascial strips, first used by Busch in 1913. Various surgeons have improved the technic so that at the present time while there are many variations, the principle is still the same. At

least three strips of fascia are needed, each measuring approximately 4 to 5 mm wide and approximately 10 to 20 cm. long. These are obtained from the fascia lata of the thigh. An incision is made over the temporal area, extending approximately 1 cm. above the insertion of the helix of the ear upward and outward in the edge of the hairline for 6 cm (Fig. 221, *A*). Using a sharp heavy probe, a tunnel is made between the subcutaneous tissue and fascia, beginning at the lower edge of the incision and carried down to just above the angle of the jaw, around, across the midportion of the lower lip past the midline where a small incision is made in the skin to permit exit of the end of the probe. A piece of fascia is tied to the probe and the probe is withdrawn, pulling the fascia along the track. Through the incision on the chin the fascia is carried through the muscle on the normal side, including approximately 1 cm. of muscle, and brought backward and sutured to itself with interrupted four 0 silk. The upper end of the fascia is carried through an incision in the temporal fascia 0.5 cm in length. The strip is pulled upward to elevate the lower portion of the cheek. This is tightened as much as possible and sutured to itself with interrupted four 0 silk. The other fascia strips are inserted in a similar manner to the corner of the mouth and to the midportion of the upper lip just past the midline. All strips are sutured to the muscles as described, and the incisions are closed in layers. An external adhesive support, strapping the face upward on the involved side, is essential (Fig. 221, *B*). There will be, in most instances, moderate swelling of the entire face for ten days to two weeks. During this period it is advisable to maintain the external strapping to prevent undue stretching of the underlying strips. After all swelling has subsided, the strapping can be removed. It will be noted at first that this side of the face will probably be exaggerated in an elevated position. The patient is encouraged to massage the entire cheek gently with cold cream for ten to fifteen minutes daily until sufficient relaxation is gained to give a normal appearance.

THE EYELIDS

Operations on the eyelids are usually for excision of neoplasms or for deformity caused by trauma, ulcer, burns, or the removal of neoplasms.

Entropion

Occasionally the eyelids turn in—entropion—and the operation for this condition consists in removal of tissue from the external surface of the upper and

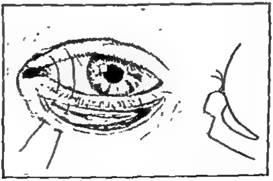

Fig. 222.—Snellen operation for entropion due to old acid burns of inner portion of lower eyelid. A wedge-shaped section of the tarsus is excised and two silk sutures are placed. Inset is a vertical section through the lower lid before sutures are tied.

lower eyelids. The excision includes not only the skin but some of the thickened tarsal cartilage and is made in such a manner as not to disturb the margins of the lid. Many operations have been devised for the correction of entropion. In our experience, Snellen's method seems satisfactory where the conjunctiva is scarred and the tarsus is distorted. A narrow elliptical section of skin is removed from the eyelid, parallel and close to the lid margin. The fibers of the orbicularis muscle are separated and retracted, and a wedge-shaped piece of the tarsus is excised. Fine silk sutures are passed through the skin and the tarsal segment distal to the lid border (Fig. 222).

Ectropion and Reconstruction

The most common deformity of the eyelid is eversion, or ectropion. If the contraction which caused ectropion were located in one spot or confined to one line, the operation for the correction of this condition would be comparatively simple. Unfortunately, however, the surrounding tissues to a considerable extent are usually affected by the scar tissue. It is often difficult to secure a sufficient amount of normal skin to give satisfactory support to the eyelid.

The types of operations that are applicable may be divided into (1) skin grafting with free grafts, (2) sliding flaps or pedicle flaps from the adjacent tissue, and (3) migrating pedicle flaps from a distant part. These operations are suitable for either ectropion or reconstruction of the lids. The only difference is that in reconstruction of the lids, where the conjunctiva and the tarsal cartilage are absent, it is essential to have the inner raw surface of the graft covered with epithelium. To accomplish this an Ollier-Thiersch skin or mucous membrane graft is placed on the flap before it is shaped into an eyelid.

Skin grafting for eversion of the upper or lower lids is not satisfactory as a rule unless whole or thick split skin grafts are used. If the eversion is due to contraction of a scar, and the scar is excised and an Ollier-Thiersch graft applied, a recurrence of the contraction may be looked for unless the scar is very superficial. In order, then, to correct contraction in a deep injury of the eyelid, it is necessary to transplant thicker skin grafts. When the operation is for ectropion where the tarsal cartilage and the conjunctiva are well preserved, these grafts usually give excellent results. It was for this type of operation that the full thickness skin graft of Wolfe was originally devised. If there is considerable infection about the eye, which cannot be cleared up, the graft may not be successful.

Gillies finds that, when the scar contraction of a lid is very superficial and all of the corium has not been destroyed, the use of Ollier-Thiersch grafts may be successful. The eyelid is mobilized and the scar dissected away (Figs. 223, 224, and 225), then the graft is applied to a mold of dental wax made to fit the defect, with the raw surface of the graft external (Fig 226). The mold covered with the graft is fastened in the defect with sutures which catch the margins of the graft (Figs. 227 and 228). The sutures and the mold are removed in a week or ten days (Fig 229).

In many operations upon the eyelid, the lids are sewed together after trimming the eyelashes. Occasionally, it is better to overcorrect the lids by overlapping them. If, for instance, the lower lid is to be operated upon, it may be folded over the upper and the sutures in its edge are fastened to the forehead by adhesive plaster. This method has been made use of by a number of surgeons to obtain

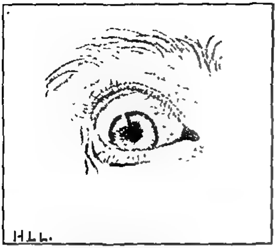

Fig. 223.—Line of incision for releasing contraction of the upper lid according to operation of Gillies.

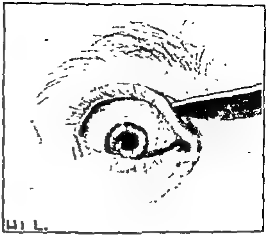

Fig. 224.—Dissection of contraction of upper lid.

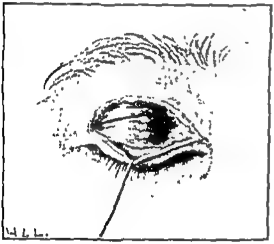

Fig. 225.—The upper lid is freed and turned down.

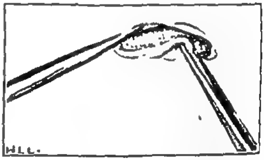

Fig. 226.—Ollier-Thiersch graft is placed on a mold of wax. (Gillies.)

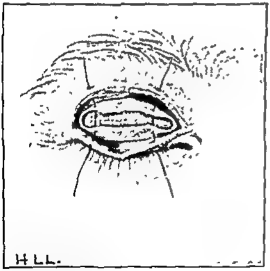

Fig. 227.—The mold, with the graft placed with the epithelium next to the mold, is sutured into the raw surface left by dissecting the contractions of the upper lid (Gillies.)

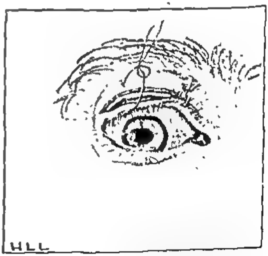

Fig. 228.—The sutures which catch the skin of the lids and the graft are tied. The sutures and mold are removed in about ten days. (Gillies.)

overcorrection while the lid is healing. Because there is a tendency to contraction, it is highly essential to overcorrect the lid in any plastic operation. (Figs. 230 and 231.)

If skin grafts cannot be used satisfactorily, the method of sliding flaps from the neighborhood may be considered. The operation to be selected depends to a large extent upon the character of the contraction. If the contraction is linear or very limited, the operation of Wharton Jones is excellent. Here a V-shaped incision is made, beginning at each extremity of the lower eyelid and uniting at an acute angle

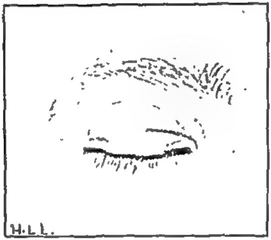

Fig. 229.—The late result of operation of Gillies for eversion of upper lid.

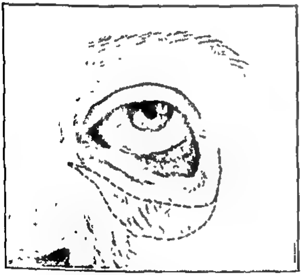

Fig 230. Fig 231.

Fig 230.—Before operation. Dotted lines indicate incisions for first operation.

Fig 231.—Completion of first operation Indurated scar area of cheek and lower lid is excised, lower lid and adjacent cheek are mobilized, eyelids are sutured, and a full thickness skin graft is transplanted from the inner side of the arm to defect.

some distance below the lid. If the contracting band is in the midline or near a line of the incision, it is thoroughly excised The skin is well undermined along the margins of the incision and the wound is sutured, thus converting the V-shaped incision into a Y and so pushing up the lower lid (Figs. 232 and 233). The method of Dieffenbach can also be used. This consists in taking a quadrangular

flap whose upper end is about on the level of the normal upper border of the lower lid when the eye is closed, but external to the outer canthus of the eye. The base is below and inward. After excising the scar tissue or the growth below the eyelid, this flap is slid inward to replace the excised area and the triangular denuded area is partly sutured and partly covered by a graft (Figs. 234 and 235). A flap can also be taken with its base near the outer canthus and extending either downward or upward, or with its base near the inner canthus and extending downward. This flap may be turned into the raw surface left by excision of the scar tissue of the lower lid. A quadrangular flap may be slid according to the method of Knapp on a horizontal plane with the defect caused by excising the scar tissue of the lower

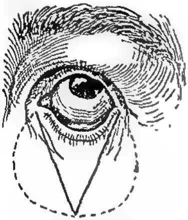

Fig 232.—Lines of incision for the Wharton Jones operation for ectropion of the lower lid.

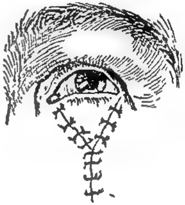

Fig. 233.—The operation of Wharton Jones completed.

Fig. 234.—Lines of incision for operation of Dieffenbach for ectropion of lower lid.

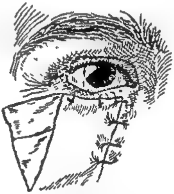

Fig. 235.—Operation of Dieffenbach completed.

lid (Figs. 236 and 237) If the deformity is confined to the lower lid and there is a redundancy of tissue in the upper lid, a flap of skin may be turned down from the upper lid with a single pedicle hinge, or visorlike (Figs. 238 and 239). A strip of skin is cut from the upper lid by two parallel incisions, which form a bridge of tissue attached at its two ends, one above the outer and one above the inner canthus of the eye. This bridge is turned down to the lower lid according to the method of Landolt, and sutured in position.

The method of Monks consists in outlining the eyelid on the forehead and dissecting out a pedicle containing the anterior branch of the temporal artery and vein with some surrounding connective tissue This flap is carried under a tunnel burrowed from the lower end of the incision, so that the anterior temporal artery

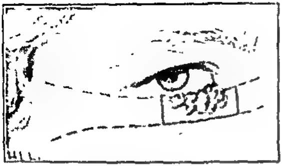

Fig. 236.—Lines of incision for operation of Knapp for repair of lower lid.

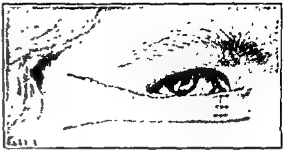

Fig. 237.—Operation of Knapp completed.

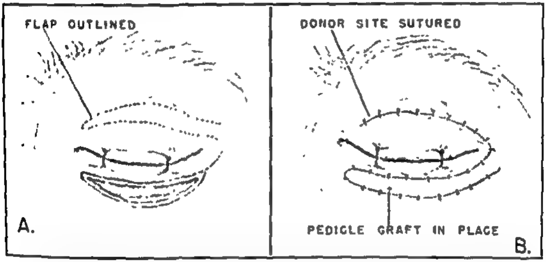

Fig. 238.—Repair of scar tissue contraction of the lower lid with pedicle from the upper lid. *A,* All scar tissue is excised and the adjacent skin undermined. The edges of both lids are sutured together. The pedicle flap is outlined on the upper lid with the base on the outer canthus. *B,* The flap is swung into place and sutured with interrupted silk sutures.

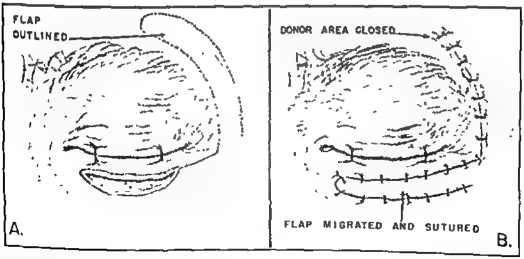

Fig 239.—Repair of scar tissue contraction of the lower lid with pedicle flap from the temple *A,* All scar tissue is removed from the lower lid. The edges are undermined A pedicle flap from the adjacent temple skin is outlined *B,* The flap is rotated and sutured into the lower lid with interrupted silk sutures

nourishes the reconstructed lower lid (Figs. 240, 241, and 242). On account of defective venous circulation, this principle is unsatisfactory in larger flaps.

Gibson uses a quadrilateral flap. A horizontal incision is made from the outer canthus of the eye and an Ollier-Thiersch graft is tucked in (Figs. 243 and 244). After the graft has taken, this is shaped into a quadrangular flap and is slid inward to supply the defect in the lower lid (Figs. 245, 246, and 247). Only the outer half of the lower lid can be reconstructed by this method. For the inner side of the lid a flap may be taken from the bridge of the nose and turned down.

Fig. 240.—Operation of Monks for repair of lower lid. A flap is dissected from the forehead with the temporal artery as pedicle.

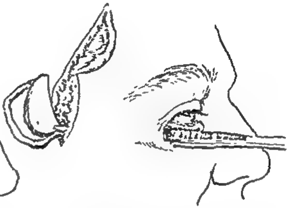

Fig. 241.—The flap is freed and caught with forceps, to be drawn through a tunnel from the lower lid to the temporal artery.

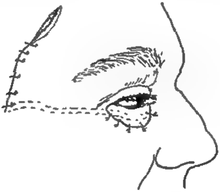

Fig. 242.—The operation of Monks completed

It must constantly be borne in mind that, if the operation is for reconstruction of the full thickness of the lower lid and not for correcting eversion, whole skin grafts cannot be used, for it is necessary to cover the raw surface next to the eye with mucous membrane or an Ollier-Thiersch graft. This lining should be grafted on a flap two weeks before the flap is turned into its position, as it is difficult or impossible to line the flap after it is transplanted. If it is not thus covered, contraction of the raw surface will interfere with the success of the operation. (Fig. 248.)

Flaps from a distance are obtained from the neck or arm or migrated from the anterior trunk. If from the neck, a long narrow flap is cut, according to the method of Snydaker-Morax, with the base about the mastoid region and the tip of the flap over the sternoclavicular articulation (Figs. 249 and 250). As such a

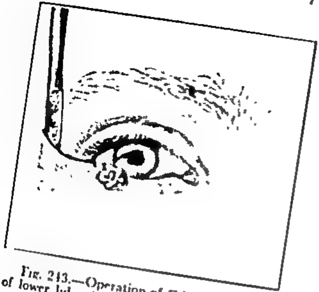

Fig. 243.—Operation of Gibson for repair of lower lid. A pocket is made for the reception of graft.

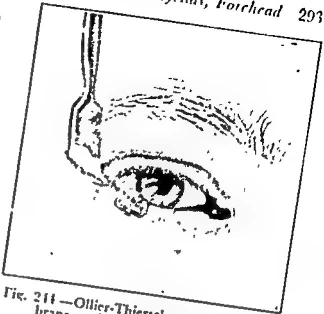

Fig. 244.—Ollier-Thiersch or mucous membrane graft is placed in position.

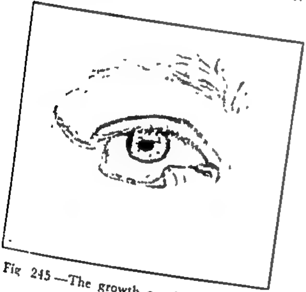

Fig. 245.—The growth on the lower lid is excised.

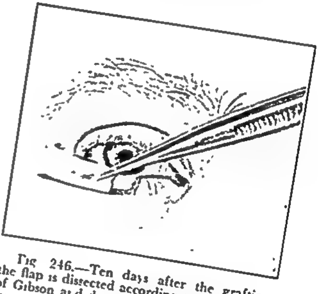

Fig. 246.—Ten days after the grafting the flap is dissected according to the method of Gibson and drawn over the defect in the lower lid.

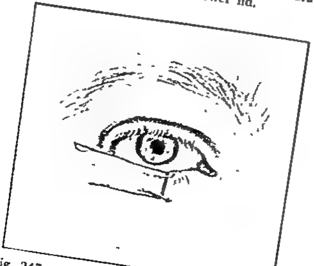

Fig. 247.—The operation of Gibson completed.

flap is long and narrow, it would be safer first to make a bridge of the tissue for the flap, then "tube" the pedicle, and gradually cut the distal end so as to establish firmly the circulation.

A pedicle flap from the arm may be obtained for the eyelids. It should be from the inner surface of the arm or from the inner surface of the forearm. A pedicle flap from this region is taken with a broad base and with a flap large enough to have an abundance of tissue. The eyelids are denuded by thoroughly dissecting away the scar tissue and sewing the lids together. If only the lower lid is everted, a flap is sewed in this position, but if both lids are affected, a large flap is made to cover both lids. The pedicle is severed in about two weeks, and a week later the flap is incised to make both upper and lower lids.

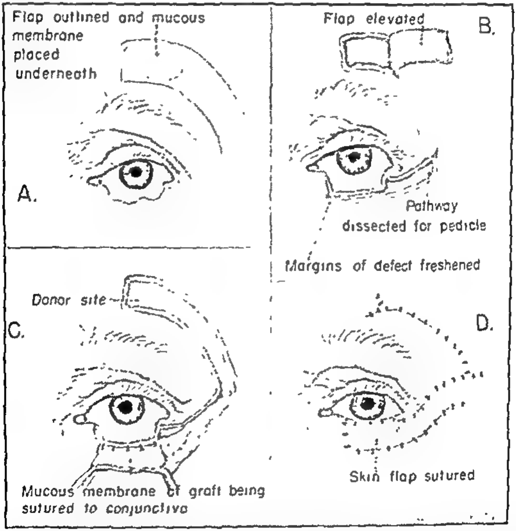

Fig. 248.—Repair of loss of entire lower lid with pedicle flap from the forehead. *A,* Pedicle outlined and mucous membrane graft from cheek implanted beneath the end of the pedicle. *B,* All scar tissue is removed from the lower lid and the flap is elevated. *C,* The flap is rotated to the lower lid and the mucous membrane is sutured to the adjacent conjunctiva with interrupted six 0 silk sutures. *D,* All wounds are closed with interrupted silk sutures.

In eversion of the eyelids which has existed for a long time, either as a result of cicatricial contraction or because of a paresis of the tissues as in senile ectropion, a V-shaped section of the lid should be removed. This includes the conjunctiva and the tarsal cartilage, as well as the skin. The wound is sutured carefully with

Fig. 249.—Lines of incision for operation of Snydaker-Morax for repair of both lids.

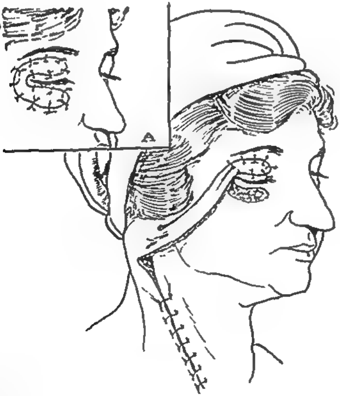

Fig. 250.—The pedicle has been sutured into position to the upper lid. Ten days later (*A*) the pedicle is cut and the lower portion of the flap is turned into the defect of the lower lid.

fine silk so as to bring the tissues into accurate approximation (Fig. 251). At the margin of the lid where there is the greatest strain, it is wise to insert a somewhat stouter silk suture. Excision and suturing may be all that is necessary for atonic ectropion. In ectropion from scar tissue contraction, however, it is only one step of the operation and should be followed by either a whole skin graft or a flap operation.

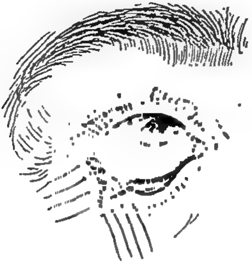

Fig. 251.—Excision of V-shaped section of lower lid for senile ectropion. Operation of von Ammon.

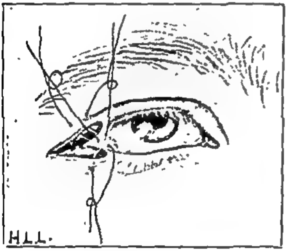

Fig. 252.

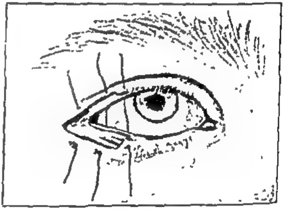

Fig. 253.

Fig. 252.—Lengthening the outer canthus of the eye according to von Ammon-Agnew.
Fig. 253.—Narrowing the outer canthus of the eye according to Walthers.

Deformities that involve shortening or lengthening the palpebral opening can easily be corrected along the principles of plastic surgery. If the opening is to be lengthened, the outer canthus is split or a triangular area excised and the conjunctiva is sutured to the skin (Fig. 252). In shortening the palpebral tissue, a triangular area including the outer canthus is denuded and sutured as a straight line (Fig. 253).

After extensive operations for cancer of the lids, involving the eyeball, it is sometimes difficult to close the socket of the orbital cavity. The bone furnishes

scant nutrition for the scar and frequently the contraction and pulling on the surrounding tissue cause great deformity and pain. After denuding the cavity a flap from the forehead, neck, or arm may be transplanted to this defect.

PTOSIS OF EYELIDS

Drooping, or ptosis, of the upper eyelid is due either to redundancy of tissue or to paralysis. Redundant tissue, which often follows other plastic operations, is corrected by simple excision of the excess skin with proper closure. Occasionally a transverse ellipse of tarsal cartilage may also be removed. Many complicated operations have been devised for congenital and paralytic ptosis. The so-called fascia sling operation will be considered first. This method is advocated for unilateral or bilateral ptosis where third nerve paralysis is complete. It is important to know the normal position of the lid margins and the average dimensions of the palpebral opening. Normally, the upper lid margin should be midway between the pupillary margin and the upper limbus when the eye is looking straight ahead. A vertical height of 9 mm. is the normal palpebral opening in the adult. The distance between the central lid margin and the arch of the eyebrow in a young adult measures from 15 to 18 mm. With ptosis this distance may increase to as much as 25 to 30 mm.

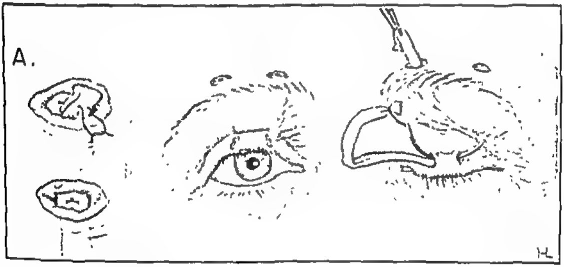

Fig 254.—Repair of ptosis of the eyelid with fascial sling *A*, The ends of the fascia are folded over before being sutured, to give additional strength.

The method which is described by Blair, Brown, and Hamm seems to be the most satisfactory operation. The basis of this operation is the attachment of the lid to the frontalis muscle by fascial bands (Fig 254). It is necessary to obtain two strips of fascia lata from the thigh 2 to 3 mm wide and 10 cm. long. Two small incisions are made 0.5 cm. above the eyebrow over the midportion of the upper lid about 1.5 cm. apart. Two small incisions 2 to 3 mm. in length are made 1 cm apart about 2 mm. above the tarsus of the eye. A needle with an eye large enough to admit the fascia is passed through the upper incision down through the muscular layer of the upper lid and out through the external incision above the tarsus. The fascia at this point is tacked to the tarsus with six 0 silk sutures. The needle is carried back through this incision beneath the skin to the medial incision

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CHAPTER 21

PLASTIC OPERATIONS ON NOSE AND EAR

LEROY SMITH

Tissue loss of the dorsum of the nose is frequently the result of traumatic injury or of the resection of the dorsum of the nose because of malignant growths. If the area involves only the skin, plastic repair is relatively simple; whereas if there is loss of bone and cartilage, repair is necessarily more involved. Skin defects involving areas of less than 1 cm. can be closed by undermining the adjacent skin and using a sliding pedicle flap to permit closure (Fig. 257). If the area is larger than 1 cm., it is often necessary to replace the skin by either a pedicle, a split or full thickness graft. Almost any portion of the dorsum may be easily covered by a pedicle flap which is outlined over the forehead, using a supraorbital arterial supply. The flap is planned with its base over one of the supraorbital vessels. The length and width is outlined so that when it is swung over the dorsum there will be adequate tissue to cover the wound. This is left in place for at least two weeks, after which time if the edges of the flap have healed well to the nose, the pedicle can be divided and returned to its original site. The upper edge of the resulting graft is sutured to the adjacent skin of the nose. (Fig. 258.)

If there is a granulating wound or if the bone and cartilage have not been entirely denuded of the superficial blood supply, a split thickness or full thickness graft may be applied. When this is done, it is usually desirable to get the skin for the nose from behind the ear or from the neck so that some of the qualities of the facial skin will be retained, namely those of color and texture.

In instances in which there has been loss of bone or cartilage, it is necessary to replace not only the skin but also the supportive structures of the nose. It may be added that in these deformities it is necessary to have a lining as well as a superficial covering. In these cases one must use a pedicle flap in order to bring in viable tissue, and the flap must be lined before its application to the nose. In elevating a flap from the forehead or other places, such as a tube pedicle from the neck, the area to be repaired is outlined as to the size and thickness and whether or not a lining is necessary If a lining is desired, this is performed by applying a split thickness graft to the undersurface of the end of the pedicle to be used. The *flap is* returned and sutured into its original site for ten days It is then elevated, and as the split graft will have healed by this time, the pedicle can be transferred. All of the surrounding scar tissue of the skin of the nose is extensively resected in order to obtain a satisfactory blood supply to the wound edges. The flap is sutured into the defect of the nose and left for two to three weeks, depending entirely upon its healing. Before

the division of the pedicle, it is necessary to test the blood supply of the graft by first constricting the pedicle one to two minutes every half hour the first day and doubling this time until the pedicle can be constricted ten to fifteen minutes without any visible change in color. This assures the operator that the blood supply of the flap is adequate, and the division can be done without danger. After division the flap is returned to its original site and the edge of the graft is sutured into the

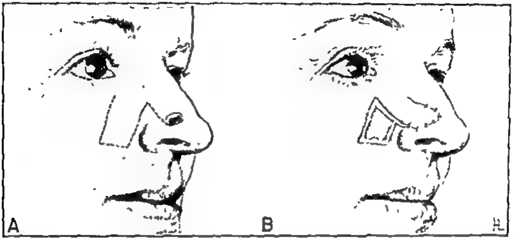


Fig. 257.—*A*, Outline of a sliding flap on the side of the cheek prepared to cover defect of the dorsum or side of the nose. *B*, The pedicle flap is transferred over the defect. The donor site is closed by undermining the adjacent skin edges and closing them with interrupted silk sutures.

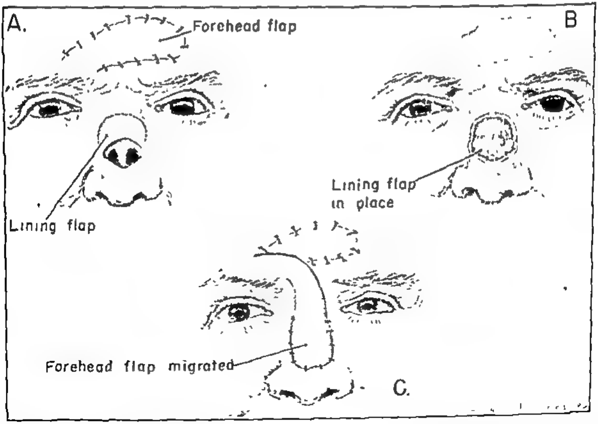


Fig 258.—*A*, Large defect of the dorsum of the nose Outline of pedicle flap on the forehead using the supraorbital vessels as a source of blood supply. *B*, The skin immediately superior to the defect is elevated and sutured in an inverted position to the lower edge of the defect to serve as a lining *C*, Pedicle flap sutured in place.

adjacent tissue of the nose with interrupted silk sutures. It may be necessary to decrease the amount of subcutaneous tissue incorporated in the graft to prevent a bulbous deformity; however, this should not be done until about three to four months following operation as there will be, of course, some shrinkage and, if thinned out at the time of transfer, a noticeable defect may occur.

After such a graft is applied, it may be necessary to replace supportive structures to the dorsum. This can be done in approximately three months following healing. Support can usually be managed by using either cortical bone or cartilage grafts. In the first instance it is easier to use a bone graft from the iliac crest. This is obtained through an incision over the bone, and the amount needed for the graft is removed. The wound is closed primarily with 000 chromic catgut in the fascia and muscle and interrupted four 0 silk in the skin. The bone is shaped to fit the desired contour of the dorsum by trimming the width of the bone in a triangular fashion, tapering off the ends, and making the graft the entire length of the nose. In addition to this, the lower end should be shaped so that there is an extra amount of bone at right angles which forms the support of the tip and is incorporated into the columella (Fig. 259).

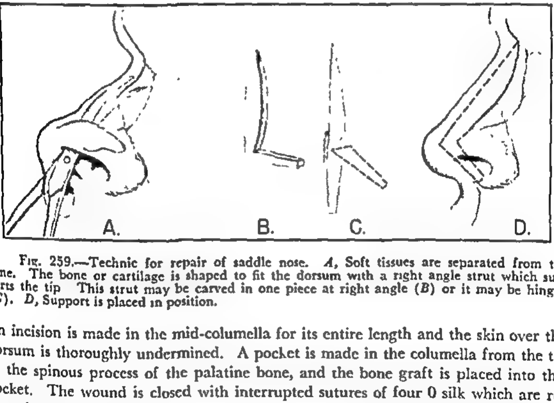


Fig. 259.—Technic for repair of saddle nose. *A*, Soft tissues are separated from the bone. The bone or cartilage is shaped to fit the dorsum with a right angle strut which supports the tip This strut may be carved in one piece at right angle (*B*) or it may be hinged (*C*). *D*, Support is placed in position.

An incision is made in the mid-columella for its entire length and the skin over the dorsum is thoroughly undermined. A pocket is made in the columella from the tip to the spinous process of the palatine bone, and the bone graft is placed into this pocket. The wound is closed with interrupted sutures of four 0 silk which are removed at the end of five days. External splinting with adhesive or with dental compound should be used and the support should be maintained for two weeks to allow stability of the graft.

If cartilage is used as a support, it is usually obtained from the seventh to ninth cartilage through an incision running parallel with the eighth rib anteriorly. The recti muscle is divided in its respective plane. The underlying cartilage being exposed, an outline of the support should be made and the necessary amount removed in one piece It is most desirable, when possible, to have the dorsal and columella strut in one piece rather than to try to use them as two separate pieces. If the latter method is used, the approximated ends at the tip of the nose are very

unstable and it is difficult to fix them in such a position that they will not at a later date become deranged. The shaping and implantation of cartilage are the same as of bone.

RECONSTRUCTION OF THE TIP OF THE NOSE

Because of traumatic injuries to the tip of the nose and loss following removal of tumors, it is often necessary to replace this part. If the entire tip of the nose is lost, a total reconstruction will have to be done. One should not jeopardize the outcome by using local flaps to repair a large defect. Either pedicle flaps from the forehead or tube pedicle flaps from the side of the neck are the most successful (Fig. 260). Flaps are sometimes used which have been raised from the arm; however, the application of such to the tip of the nose necessitates large amounts of discomfort for the patient since the arm must be strapped to the head for days. This type of graft provides no real advantage and is not recommeded. Most flaps used to reconstruct the tip of the nose must be lined. The lining may be obtained from split grafts placed under the flap or by folding the flap inward to form the inner sides of the nostrils. In order to reconstruct the nose successfully, it is imperative that the operator have a definite plan of exactly the amount of tissue needed and allow one-fourth additional amount for shrinkage. At the time of planning the original flap, a definite outline of the pattern of the new tip should be made and this should be adhered to until reconstruction is complete. A valuable aid is to prepare a plaster model of the deformed nose and outline the desired nose with wax or modeling clay.

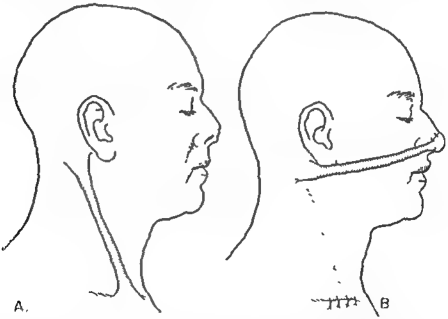


Fig. 260.—*A*, Loss of tip of nose repaired by pedicle flap from side of the neck. *B*, The distal end of the pedicle is sutured to the tip of the nose

Using a rubber dam as a pattern, this is placed over the reconstructed model so that the exact outline of the area of skin needed for replacement can be determined This pattern is placed at the distal end of the flap of the forehead or of the neck, whichever the case may be, and allowances are made for contraction by outlining this pattern for a distance of 0.5 cm beyond the exact measurements. After the flap has been prepared, the scar tissue of the nose is excised. The graft is then

folded to conform with the previously made plan and sutured with interrupted four 0 silk sutures. It is left in place for fourteen days or until it is healed and the blood supply is adequate. All sutures are left in for seven to ten days. Following division of the pedicle, it is replaced in its original site and the resulting free edge of the flap is sutured to the adjacent skin of the nose. At the end of three or four months, the scar may be reopened and the excessive skin and subcutaneous tissue are trimmed away so that the tip of the nose will not appear too large. It is not necessary to have any bony or cartilage support to the dorsum; however, occasionally it is essential to have a columella strut to support the tip of the nose. This can be done at the same time as the reshaping. A cartilage section from a rib is shaped to fit into the columella pocket made through an incision in the mid-columella and the length is measured from the spine of the palate to the desired elevation of the new tip. (Fig. 259, *D*). Following implantation of the cartilage into the pocket, the columella is sutured with interrupted four 0 silk sutures.

THE LOSS OF THE ALA, RIM, OR COLUMELLA

If a small part of the ala or rim of the nostril is lost, this defect may be corrected by outlining a flap above the defect similar to the area which has been lost and using its base at the upper edge of the defect. This flap is dissected upward, turned down, and sutured to the denuded edges of the adjacent skin. The resulting denuded area from which the graft was taken and the area overlying the graft are covered with a full or split thickness graft from behind the ear or neck. This is sutured into the wound with continuous four 0 silk sutures. This graft is treated like any other free graft until healing has taken place. In instances in which the above procedure is not practical, an adjacent flap may be outlined on the cheek and rotated to the side of the nose to fill out the deformity of the ala rim. (Fig. 261.)

A. *B.*

Fig. 261.—*A*, Lines of incision for operation of Nélaton for correction of defect of the ala. *B*, The operation of Nélaton completed.

In the rebuilding of the nose following entire loss of the ala, rim, or columella, the best repair is obtained by a pedicle flap as described for the total loss of the tip. Occasionally, when the ala or rim is lost, it may be reconstructed by a composite graft from the rim of the ear, using the helix of the ear which corresponds to the part lost. The graft is taken and sutured into the defect, following denuding of the adjacent skin edges, with four 0 silk sutures. (Fig 262.) The nostril is packed fairly firmly with petrolatum gauze and strapped with adhesive over a close-fitting

gauze bandage. This supportive bandage remains for ten days, at which time the dressings are removed and the sutures are taken out. It may be noted there is marked desquamation over the graft, and it usually takes about three weeks for it to regain its natural color.

Fig. 262.—Composite cartilage graft from ear to nose.

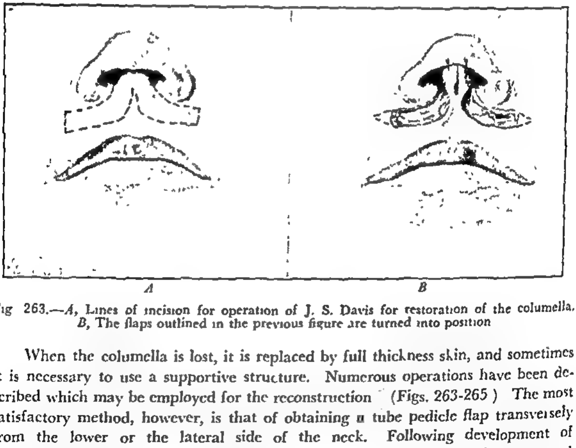
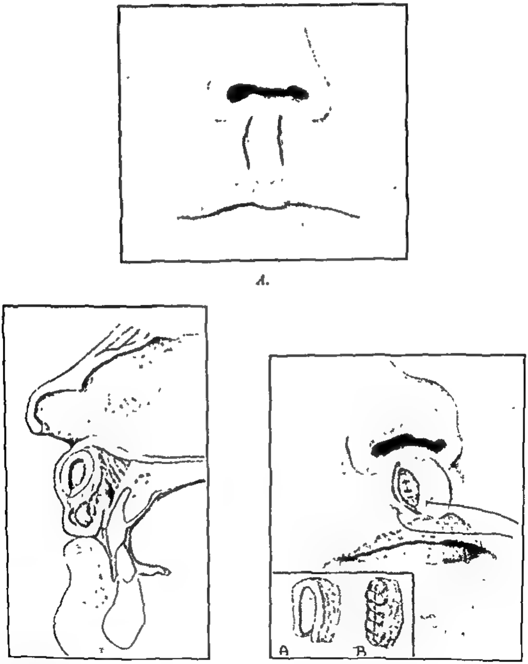


Fig 263.—*A*, Lines of incision for operation of J. S. Davis for restoration of the columella. *B*, The flaps outlined in the previous figure are turned into position

When the columella is lost, it is replaced by full thickness skin, and sometimes it is necessary to use a supportive structure. Numerous operations have been described which may be employed for the reconstruction (Figs. 263-265) The most satisfactory method, however, is that of obtaining a tube pedicle flap transversely from the lower or the lateral side of the neck. Following development of the pedicle (Fig. 266), the distal end is swung to the tip of the nose and sutured to it with interrupted silk sutures. This is left in place for two or three weeks, following which time the blood supply can be forced from the tip by constricting the pedicle at the proximal end The pedicle is amputated at a distance from the tip of the nose so that enough is left to reach the mid portion of the upper lip. This is sutured into the upper lip through a transverse incision with interrupted

four 5 silk sutures. The remainder of the pedicle is either amputated at the proximal end or may be opened and resutured into its original site. If the septum is present, the posterior end of the new columella is opened and sutured into the denuded edge of the septum. If the septum is not present, it may be necessary to give support to the tip through an anterior linear incision in which a piece of shaped cartilage can be inserted with the base resting on the spine of the palatine bone and the other end resting under the tip of the nose.



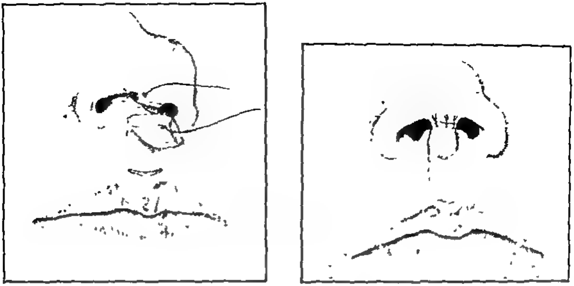
A.

B *C.*

Fig. 264.—*A*, Updegraff method of reconstructing columella. Parallel incisions through full thickness of skin.

B, Sagittal section of Updegraff operation showing the stent graft in place in the lip wound

C, Full thickness skin graft sutured over stent and placed in lip wound Inset: A, Full thickness skin folded over stent with raw surface outside; B, graft sutured over stent (Updegraff.)



A. *B.*

Fig. 265.—*A*, Lined lip flap severed and raised. First suture placed to unite reconstructed columella and denuded area behind tip of inner nose. (Updegraff.) *B*, Updegraff operation for reconstruction of columella completed.

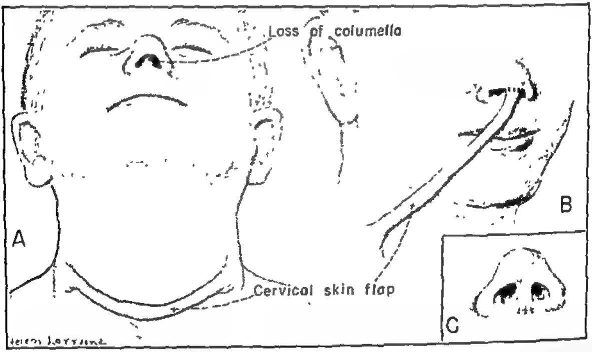


Fig 266.—*A*, The pedicle flap is developed transversely across the lower neck. The nose shows the absence of the columella. *B*, The distal end of the tube is transplanted to the tip of the nose. *C*, Operation completed by dividing and suturing the required length of the flap to the upper lip.

TOTAL LOSS OF THE NOSE

Following traumatic injury or the removal of a carcinoma, the entire nose is sometimes lost. It becomes the duty of the plastic surgeon to construct a nose which not only is pleasing from a cosmetic point of view but also has nostrils that will remain open for normal breathing. There are two methods that may be employed, one using skin from parts of the body other than the face, such as the arm, and the other utilizing the skin of the forehead either by a direct pedicle flap in the midportion of the forehead or a sickle-shaped flap over the skin of the temples as

described by New. It is not believed by the author that the latter has any outstanding advantage, and for the sake of simplicity the one described is that which seems most successful. It is necessary to have a definite idea as to what amount of skin will be needed, how much of the flap will have to be lined, and what type of support will be used. Before any operative measures are carried out, a plaster mold of the face is made and a wax nose is built on the mold with the desired dimensions in order to enable the operator to construct a nose which meets the necessary requirements. It is impossible to give any specific dimensions of the flap, as each individual case must be handled separately. Therefore, by means of a model the dimensions to be used in each case must be worked out. Following the building of the nose on the wax model, the superficial outline can be obtained by spreading over the nose a thin piece of lead or aluminum foil which will conform to the outline. The foil should cover the entire area of the dorsum and the inner nostrils and should surround the columella. By careful execution this entire area can be covered by one piece of foil, which is removed and spread out on a flat surface. Approximately 0.5 cm. of peripheral skin should be allowed in all directions to allow for shrinkage. This pattern is placed on the forehead at the end of a free flap which includes the medial half of the eyebrow, taking advantage of the supraorbital vessels for blood supply. Following the outline of the required dimensions at the end of such a flap, it is necessary to determine whether or not the flap is long enough so that when it is twisted upon itself to shift the new nose in place there will not be too much embarrassment to the base of the pedicle. It must be sufficiently long to reach the site at which the ala and columella are to rest upon the upper lip without too much tension. The latter can be readily ascertained by cutting a piece of rubber dam the shape of the pedicle and distal part of the required flap, and rotating it over the site at which the nose is to be placed. It is always best to have the pedicle slightly longer than normal to insure against disturbance of the circulation.

At the first operation the entire flap across the forehead is outlined through the skin, and the lower half is incised through the skin and subcutanous tissue down to the fascia overlying the bone. The lower half of the pedicle is undermined. This is resutured with 000 silk sutures and left for five days, at which time the upper half of the flap is elevated and resutured. If the entire nose has been lost, the upper two-thirds should be lined. The covering of the undersurface of the lower third, which includes the lining of the nostrils, is obtained by turning in the distal portion of the flap as is planned when the original pattern is made. For the lining, an intermediate graft, twice the area of the pedicle, is taken from the inner surface of the upper arm.

If the circulation seems good five days after the last operation, the flap is elevated and this intermediate graft is sutured to the posterior surface of the pedicle. A similar piece of skin is sutured over the raw wound of the forehead. Petrolatum gauze is placed between the two surfaces and the pedicle is again sutured in place. This is left for a period of approximately ten days, following which time the pedicle is elevated and the distal third of the graft on the pedicle, which is not needed, is removed. The covering for this area is made by folding in the distal end of the flap to form the nostrils and columella. (Fig 267.) The surrounding skin and mucous membrane of the wound of the nose are separated and all scar tissue is removed. The skin at the base of the columella is cut in an H shape (Fig. 267, *B*) so that by dissecting up the skin between the two sides of the H there will be a flap at the outer base and one at the inner base of the new columella, leaving the raw

surface into which the soft tissue of the end of the flap can be anchored. The umella is formed at the end of the new flap by incising two parallel lines opp the exact center for a distance of the required height of the new columella. edges of this flap are folded together and sutured with interrupted four 0 silk. two lateral flaps so formed are folded inwardly to form the inner lining of the on each side. The posterior edges of these are sutured to the edge of the lining interrupted four 0 silk. The new nose is turned down on the face and sutured

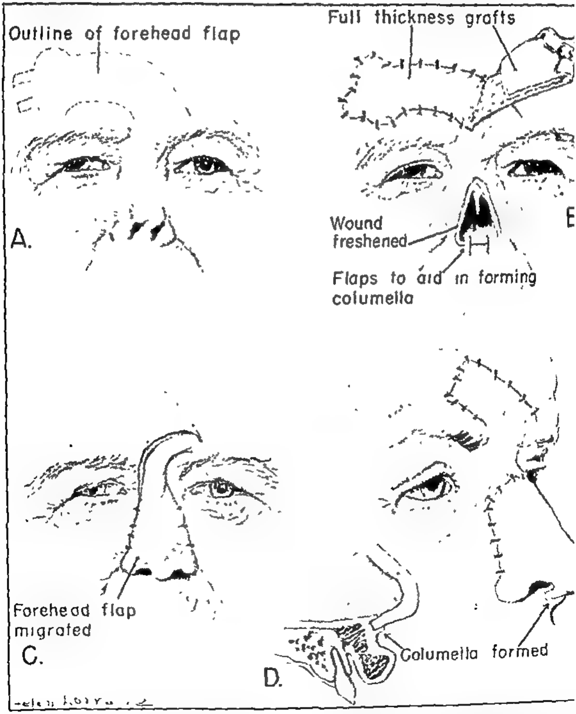


Fig. 267—Reconstruction of nose with pedicle flap from forehead *A*, The pedicle f is outlined on the forehead slightly larger than the amount of skin area necessary for rep: *B*, The pedicle flap has been lined and the distal end divided into three smaller flaps. *C*, T entire flap is rotated into place and sutured *D*, The distal end of the columella is sutu between the flaps formed by the H-shaped incision Note the normal conformity of the sl at the base of the columella. *E*, The upper end of the pedicle has been returned to original position and the operation is complete.

the surrounding skin and mucosa with interrupted silk sutures. The lower edge of the columella is denuded anteriorly and posteriorly of its skin, corresponding to the amount of skin on the flaps that is available from the previously made H-shaped incision. These flaps are sutured to the base of the new columella with interrupted sutures. No external support is needed to the nose, and a light gauze covering is used. The nostrils are packed loosely with iodoform gauze, which should be removed forty-eight hours following the operation. The raw edge of the skin surrounding the forehead wound is sutured to the split graft with interrupted silk. Following this operation care should be taken to watch the circulation of the distal portion of the nose and also to prevent any unnecessary tension or injury to the base of the pedicle. All sutures can be removed usually at the end of the eighth postoperative day without fear of separation. On the tenth postoperative day intermittent constriction of the flap is begun passing rubber bands around the pedicle so as to produce constriction of the blood supply for periods, beginning thirty seconds every hour the first day and doubling this time each day until the pedicle can be clamped for a period of ten minutes without visible embarrassment to the distal flap. At this time the flap is divided at the level of the skin of the glabella. The unused portion of the flap is spread out and the graft beneath it is removed and then returned to its original place on the forehead. The remaining edges of the new nose are sutured to the surrounding skin with interrupted four 0 silk sutures which are left in place for five days.

There is usually some edema of the entire flap for a period of two to three weeks, at which time there begins a gradual contraction. If a support is not placed into the flap before four weeks, it will be noted frequently that the contraction has been such that even with a support the nose will appear too small. For this reason it is advisable to place cartilage or bone in the nose certainly by the end of the third week. A right angle strut of cartilage is removed from the seventh or eighth rib, or a bone graft is removed from the iliac crest and shaped in an L fashion, the long end of the L being the support for the dorsum and the short end for the columella. This is inserted through a longitudinal incision in the columella. A pocket is made under the skin along the dorsum extending up to the periosteum covering the frontal bone. The pocket is carried into the base of the columella to the spinous process. The strut is inserted and the columella is closed with interrupted silk sutures. After healing, the sutures are removed, and the intake of air through the nose may not be sufficient, because there is still too much tissue surrounding the nostrils. This may be remedied by making small incisions within the nostrils and removing some of the subcutaneous tissue between the two surfaces of the skin This is known as refashioning the graft and will result in a more nearly normal shape to the nose. It may be done at any time after four weeks following operation. In patients who continue to have an insufficient intake of air through the nostrils, it may be necessary to insert soft rubber tubes in each nostril at night for a period of three to four months or longer. This practice will give confidence to the patient and it prevents undue contraction of the nostrils.

STRUCTURAL DERANGEMENT OF THE NOSE

Following trauma or, in some cases, because of abnormal development, there are various structural derangements that occur in the nose. The most frequent derangement found is a deviation of the nose to one side. In most instances this is the result of an old fracture with an abnormal approximation of the bones following

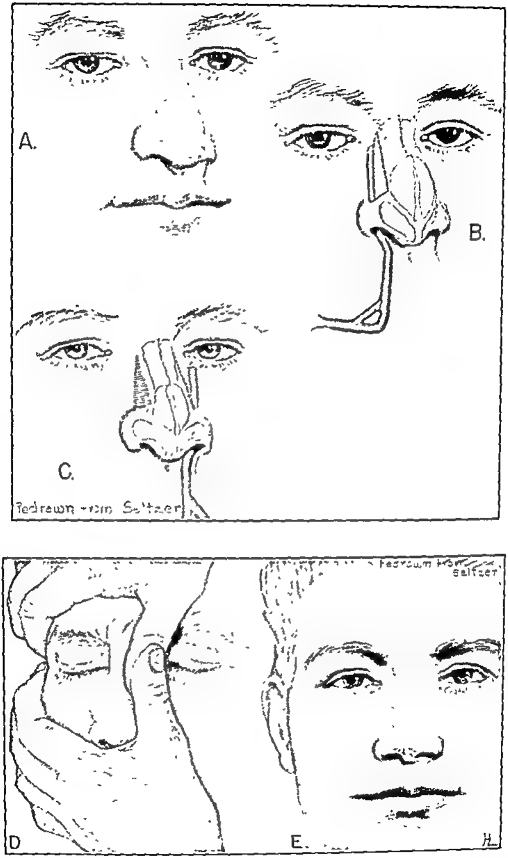


Fig. 268.—Repair of deviation of nasal septum *A,* Deviation of nose to left. *B,* Following elevation of skin over dorsum, the periosteum is elevated, and with a small saw a triangular wedge is removed from the frontal process *C,* The frontal process is sawed through *D,* With external pressure, the nose is fractured to the right. *E,* The operation is completed

injury. In such cases there is always a long and a short side of the nose. The long side is the side away from the deviation and the short side the one on which the deviation occurs. In correction it is necessary not only to move the bony portion of the nose to the midline but to remove the excessive amount of bone on the side away from the deviation. (Fig. 268, *A*.) The procedure of this operation is as follows: Under either local or general anesthetic, an incision is made within each nostril between the upper and lower lateral cartilages. With a pair of small scissors the skin over the dorsum of the nose is thoroughly undermined. The incisions between the upper and lower lateral cartilages are connected by passing a No. 11 blade from one incision to the other at the tip of the nose and extending the incision down over the septum, separating the columella from the lower portion of the septum. This produces free motion of the entire lower nose as well as the skin over the dorsum. An incision is made within the nostril on each side just within the ala and over the lower edge of the frontal process of the maxillary bone for 0.5 cm. A periosteal elevator is introduced into the incision and the periosteum is elevated

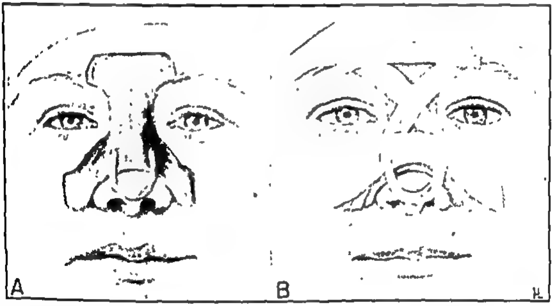


Fig. 269.—Dental mold compound splint. *A*, Mold which has been softened in warm water and cut to fit over the nose. *B*, Following hardening, the splint is strapped to the face with adhesive.

from the frontal process and nasal bones. Using a right angle saw, a triangular piece of bone is removed, with the base along the lower edge and the apex at the glabella (Fig. 268, *B*) Care should be taken not to make the lower cut too near the inner canthus of the eye for fear of injuring the lacrimal apparatus. Usually, the size of the triangle is gauged by the amount of bone it is necessary to remove to make the two sides equal. Through a similar incision on the opposite side of the nose, a cut is made in the bone with a right angle saw, extending from the base of the frontal process of the maxillary bone to the junction of the frontal bone at the glabella (Fig. 268, *C*). It is not necessary to suture these mucosal incisions. Using pressure with the thumbs on the dorsum in the opposite direction from which the deviation has occurred, the bony dorsum can be fractured free of its attachments and the nose can be moved to the midline (Fig. 268, *D*). This procedure, of course, will carry the septum, which is also deviated in these cases, to the midline (Fig. 268, *E*).

The columella is sutured to the base of the septum with two interrupted sutures of silk. The incisions between the upper and lower lateral cartilages are not sutured The nose is packed with petrolatum gauze and the correct position is maintained by using an external splint of dental compound which has been softened in hot water and molded to fit the shape of the external nose (Fig. 269). After this becomes hard, it is strapped over the nose with adhesive plaster and the entire nose is held in a normal or slightly overcorrected position. The external splinting must be maintained for at least two weeks.

Sometimes following trauma, there is a deviation of the septum which produces a shifting of the lower nose without abnormal position of the bony structures. The latter can be diagnosed accurately by internal examination and x-ray which will show the bony structure in the midline. Deviation is caused by the septum having been torn from its attachment and having healed in an off-center position. If the septum is entirely straight but is deviated, it is easily corrected by detaching the columella from the base of the septum and dissecting the attachment of the septum from the anterior spine with a sharp knife. The incision is carried posteriorly on top of the bony palate and vomer on the side away from the deviation. The septum can be brought back into the midline and held in this position either by intranasal packing or by external splinting. Before splinting, the base of the septum is sutured to the columella with interrupted four 0 silk. Such splinting is maintained for at least two or three weeks, giving the cartilage sufficient time to heal in its new location. Occasionally, there is a slight deviation of the septum at the tip, which produces a slight twist to one side or the other of the nose. In most instances this is caused by a fracture of the lower edge of the septum. This is easily remedied by separation of the columella from the septum and a resection of the deviated portion. The columella is then reunited to the base of the septum with interrupted silk sutures.

Following depressed fractures of the septum or excessive removal of its cartilage, there develops a saddle deformity of the nose. Small depressed deformities can be remedied by the submucous removal of a portion of the cartilaginous septum, under local anesthetic, and implantation of it on the dorsum. A small incision is made 0.5 cm. above the base of the septum, and through this the perichondrium is elevated from the cartilage. An incision is then made through the cartilage but not through the perichondrium on the opposite side, and the perichondrium and mucous membrane are elevated from this side with a small elevator. Through such an incision, using small blunt scissors or a swivel knife, the necessary amount of cartilage can be removed. The mucous membrane is sutured loosely back in place with interrupted fine silk sutures. The nose should be packed on both sides with petrolatum gauze to prevent hematomas forming in the septal wound. An incision is next made between the upper and lower lateral cartilages on each side. The skin over the dorsum is elevated and the piece of cartilage removed from the septum is inserted to fill out the depression over the dorsum. This can be attached either to the lower lateral cartilage or the dorsal skin of the nose, using interrupted fine silk through the cartilage graft and underlying cartilage or overlying skin. The skin is allowed to readjust itself over the graft and an external splint of adhesive plaster is applied to maintain its position. The strapping is used for one week, being removed every third day and reapplied.

Larger saddle deformities which may involve the bony portion of the nose must be repaired by the use of a dorsal graft carried through the columella. If there is a depression of the tip, a columella strut has to be used also. A piece of cartilage from the seventh, eighth, or ninth rib is used. This is shaped to fit the length and desired height of the nose. (Fig. 259.) This graft is introduced by making a longitudinal incision in the columella. Through this the skin is dissected up over the dorsum and columella to the anterior nasal spine. The graft is introduced into this pocket, the upper edge going beneath the periosteum of the frontal bone. The skin of the columella is closed with interrupted four 0 silk sutures. The position of the graft is maintained by an external splint which should be used for a period of not less than ten days.

DORSAL HUMP

Of all rhinoplastic operations, perhaps the most common is the removal of excessive bone and cartilage of the dorsum of the nose. The hump deformity may be the result of a congenital overgrowth or a traumatic injury to the nasal bone. In either case the defect is the same, producing a protrusion of the dorsum with hypertrophy of the nasal bones and the anterior edges of the upper lateral cartilages. The management in these cases is as follows: It is wise to take photographs which include a full-face and a profile view before operation is started. Using the photographs as a guide, particularly the profile, the amount of excessive hypertrophy of the nose can be determined by drawing a line from the glabella to the tip and raising or lowering this line so that it will conform to the slant of the forehead and chin. The angle formed by this line with a line drawn from the frontal protuberance to the tip of the chin is 25° to 35° and in cases of receding chins this angle has to be increased. By carrying out the above planning, the operator is able to get an idea of how much to lower the dorsum of the nose in order to give the patient a good cosmetic result. The night before operation the skin of the face should be freed of any cosmetics and the nasal membranes examined to make sure there is no impending infection as evidenced by increased redness or the excessive production of mucus. These operations are purely elective and no risk should be taken which might impair the result. The operation may be carried out under local or Pentothal Sodium anesthetic. At the start of the operation the skin of the entire face is painted with iodine and alcohol or tincture of Merthiolate All hairs are removed from the nostrils and the inside of the nose is cleansed with 70 per cent alcohol An incision is made between the upper and lower lateral cartilages With a pair of blunt scissors the skin over the dorsum of the nose is undermined (Fig. 270, *A-D.*) The incisions at the apex of the nose are joined by passing a pointed blade over the tip of the septum and carrying the incision down between the columella and the septal cartilage This separates the tip of the nose from all attachments A small periosteal elevator is introduced into the nose through the incisions, and the periosteum of the nasal bones is elevated up to the glabella. Using a right angle saw made for the respective sides of the nose, the cut is begun at a level which has been selected to give the desired height to the dorsum. The bony portion of the nose is sawed through on one side and the saw is removed The second saw is introduced on the opposite side and this cut is made in the same plane so that the two will coincide at the base of the hump. Following detachment of the bony hump,

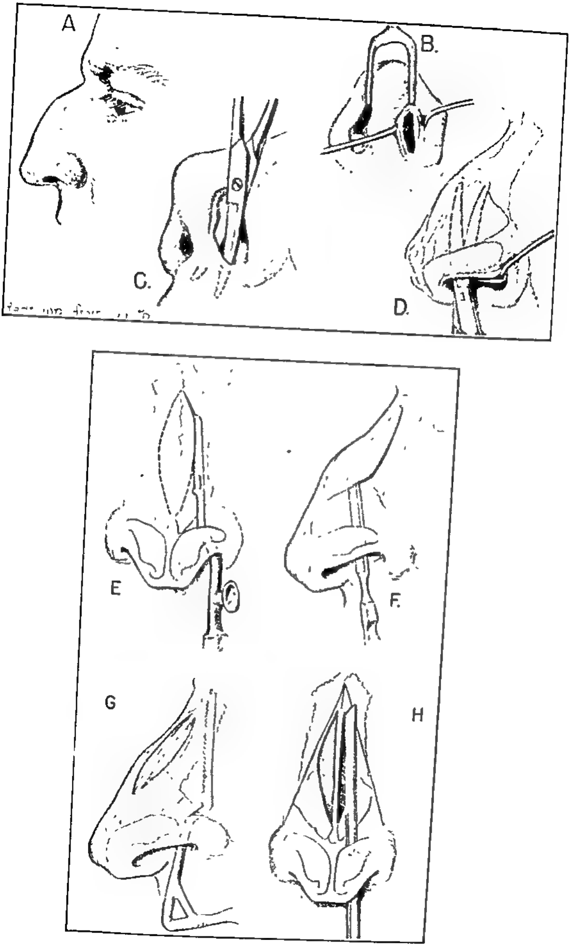


Fig 270. *(For legend see opposite page.)*

a blunt-edged knife is introduced and the cartilaginous hump, consisting of a portion of the septum *and the anterior edge of the upper lateral cartilage, is removed.* (Fig. 270, *E-H.*) The severed tissue is removed from the nose through the nostril incisions. Any small tough edges of bone are smoothed down with a rasp.

At this stage it will be noted that the height of the nose is normal but there is excessive width due to removal of the apex of the triangle of the dorsum. It is now necessary to narrow the nose. An incision 0.5 cm. in length is made in the mucosa over the lateral wall of the nose at the level of the mucocutaneous border. Through this incision a small periosteal elevator is inserted and the periosteum over the frontal process is elevated on an angle toward the glabella. A right angle saw is introduced through the incision so that the point of the blade rests at the denuded area of bone at the glabella, passing across the frontal process of the maxillary

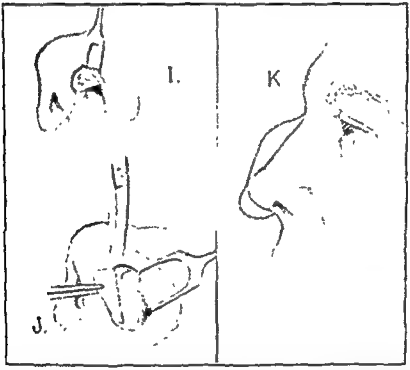


Fig. 270.—Rhinoplasty for dorsal hump *A*, Bony and cartilaginous hypertrophy of the dorsum of the nose. *B*, Incision between upper and lower lateral cartilages, bilateral. *C*, *Columella* separated from the septum. *D*, Skin over the dorsum undermined. *E*, Excessive bone cut with saw. *F*, Excessive cartilage cut with sharp knife. *G*, Excessive bone and cartilage have been removed in one piece and nasal bones separated with chisel at the glabella *H*, Through small incisions within the ala, the frontal process is sawed through along the line *from the* glabella to the base. *I*, The tip of the upper lateral cartilage is removed. *J*, Removal of tip of septum to shorten the nose. *K*, Results following completion of the operation.

bone, its lower edge resting at the junction between the lateral edge of the bone and the pyriform opening The bone is sawed through and the same procedure is repeated on the opposite side. Using straight scissors, the lower edges of the upper lateral cartilages are detached from the septum on each side. A small chisel is inserted into the nose and the attachment of the nasal bones with the perpendicular plate of the ethmoid is separated. With pressure on each side of the nose, the bones are fractured to the midline. All bone sawdust is carefully curetted from each cut. Because the height of the nose is lowered, it will be found necessary to shorten the nose slightly to compensate for this. This is accomplished by exposing the base of the septum and resecting a *small triangular piece along the base, usually* 0.25 to

0.5 cm. in width at the top This should be carried down to and should include the nasal spine. By holding the columella in approximation with the base of the septum, it will be noted there is a slight protrusion of the tips of the upper lateral cartilages into the nostrils. These tips are resected with a pair of scissors. (Fig. 270, *I-K.*) The columella is sutured to the septum with two interrupted mattress sutures of four 0 silk. Each nostril is packed loosely with petrolatum gauze strips The position of the bones is maintained by an external splint of modeling compound which has been softened in warm water and cut to fit the size and shape of the nose. It is allowed to harden and then strapped securely to the face with adhesive. Following operation the packing is removed from the nostrils at the end of twenty-four hours and the external splint is removed and reapplied at the end of forty-eight hours External fixation is continued throughout the first week.

HYPERTROPHY OF THE TIP

Hypertrophy of the tip is caused by excessive overgrowth of the lateral wings of the lower lateral cartilages, which produces an increase in the prominence of the tip by adding to the height and width. The hypertrophy can be corrected as follows (Fig. 271): Incisions are made between the upper and lower lateral cartilages extending over the base of the septum. The skin over the lower portion of

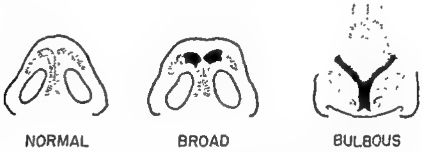


Fig 271 —Correction of tip of nose. Areas in black represent the amount of cartilage removed to narrow a broad and bulbous nose.

the nose is separated with blunt scissors. An incision is made parallel to the septum at the apex between the medial and lateral portions of the lateral cartilages This is carried backward so as to separate the two parts entirely. The upper edge of the lateral wing is pulled downward and forward to expose the entire surface and the desired amount of this cartilage plus the underlying mucosa is excised along its upper edge. The amount removed, of course, is determined by the amount of hypertrophy If there is an excessive prominence of the tip of the nose, the anterior or top portion of the medial half of the cartilage can be removed to lower the tip to its desired height. No sutures are necessary to maintain these cartilages in position. They are pushed backward into their positions and maintained there with petrolatum packing. No support is necessary.

On rare occasions one sees a prominence of the columella which produces a drooping deformity. Correction can be accomplished by removing the excessive amount of skin and subcutaneous tissue between the medial portion of the lower lateral cartilage and the base of the septum. The septum is detached by through-and-through incisions from the columella. The required amount of skin and sub-

cutaneous tissue is removed by an elliptical incision from the posterior surface of the columella. The columella is then reunited to the base of the septum with interrupted four 0 silk sutures.

SUBTOTAL AND TOTAL LOSS OF EAR

Because of the prominence of the ears, any injury to the side of the head will frequently result in their partial or total loss (Fig. 272). Congenital deformities and resection account also for many problems of ear restoration. Subtotal loss is usually confined to the helix, concha, or lobule. In general, the repair of defects of any one of the three can be readily carried out by rotating skin flaps from the posterior ear or skin overlying the mastoid process. In repairing a partial loss of the helix, an incision is made in the skin overlying the skull posterior to the ear and corresponding to the defect (Fig. 273). The wound of the ear is freshened and the posterior skin of the ear is sutured to the skin along the anterior portion of the incision with continuous sutures of silk. The skin on the anterior surface is sutured to the skin on the posterior edge of the incision with interrupted or continuous silk sutures. This is allowed to stay in place for ten days. After healing has been assured, a rectangular flap corresponding to the area of skin necessary to fold on itself to form the new helix is outlined on the skin over the mastoid region of the skull with the base along the anastomosis. This entire flap is dissected upward and the skin of the posterior ear is incised along its healed edge. The posterior edge of the flap is sutured to the posterior edge of the ear. The upper and lower edges of the flap are sutured to the adjacent skin of the helix. The wound of the post-auricular surface is closed in a straight line with interrupted sutures. If the wound is too large for such a procedure, a small split thickness graft from the arm or leg may be sutured into it as a covering. All stitches of the flap may be removed at the end of seven days, and, if necessary, at the end of six weeks the flap may be elevated and any necessary thinning out can be done at that time It is not advisable to do this under six weeks because often what appears to be an excessive amount of tissue immediately following operation will later undergo contraction.

Perforation of the concha of the ear may be repaired by dissecting up a rectangular flap from the skin overlying the skull immediately posterior to the ear (Fig. 274). This flap should be slightly larger than the defect to be covered. The edges of the perforation are freshened. The flap is rotated to fit into the perforation with the external surface to the anterior surface of the ear and is sutured with interrupted silk sutures. This is allowed to heal for approximately ten to fourteen days. After this time the pedicle is severed at the base and the excessive skin is folded on itself to form the posterior skin surface of the ear. This is sutured to the posterior surface with interrupted sutures. The raw surface from which the graft was taken is closed by undermining the skin edges and closing it with interrupted sutures.

The most satisfactory method of replacing a lobule of the ear is the utilization of a skin flap immediately beneath the lobule (Fig 275). An estimate of skin necessary to replace this can be obtained from the opposite ear. A flap one-third larger than the normal lobule is outlined on the skin immediately below the ear, and an incision is made along the upper portion, this flap corresponding to the freshened edge of the lower part of the ear The lower border of the ear is sutured

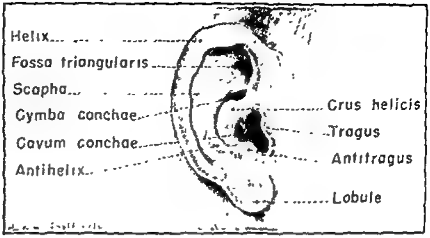


Fig. 272.—The normal ear.

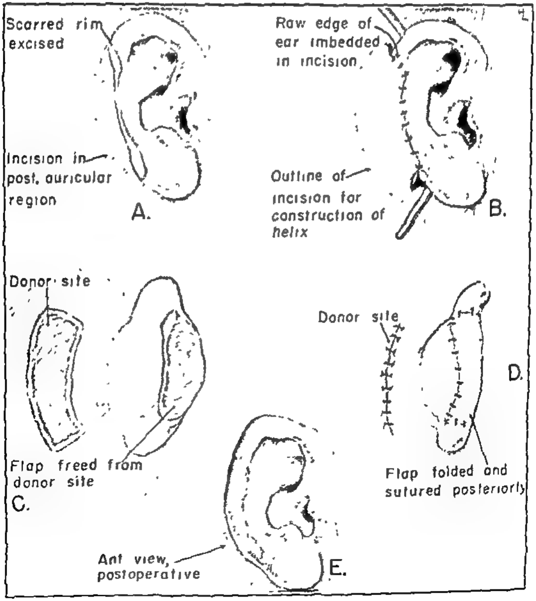


Fig 273.—Repair of loss of mid portion of the helix of the ear.

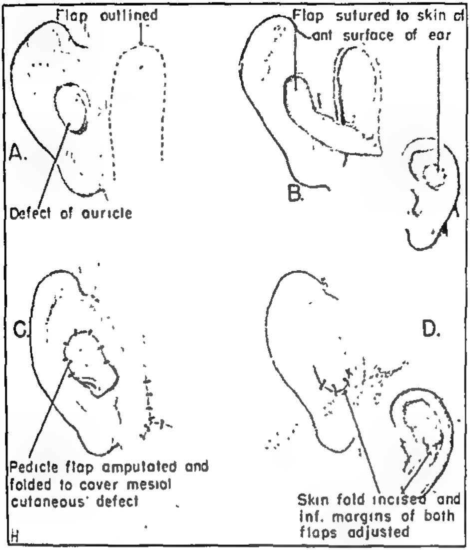


Fig. 274.—Repair of perforation of ear with posterior pedicle flap from skull.

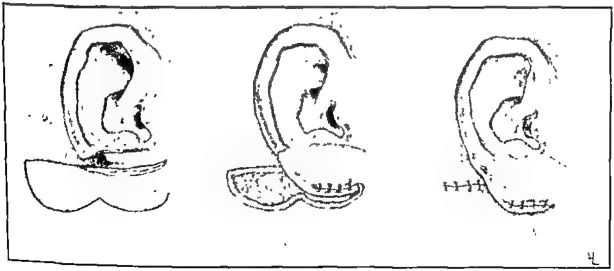


Fig 275.—Repair of lobule of ear with infra-auricular skin flap

into this incision with interrupted fine silk sutures. This is left in place approximately two weeks, at which time the lower border of the flap is incised with its edge corresponding to the general shape of the lower border of the lobule. At the same time a flap is made adjacent and posterior to the first flap on the skin, corresponding in shape to the first flap. The entire lower border of this is elevated, undermined, and resutured. This is allowed to heal for two weeks and then the entire flap is elevated from the skin of the neck, leaving the attachment of the first flap to the lower border of the ear. The flap is folded on itself, as shown in Fig. 275, and sutured around the lower edge with fine silk. The posterior skin of the ear is sutured to the posterior skin flap. The wound of the neck is closed with a linear incision by undermining the surrounding skin. It will be found that the flap maintains its general shape but there is usually an excessive total amount of skin. In six weeks this can be thinned and reshaped to conform to the lobule of the other side.

No operation is more difficult and more generally unsatisfactory than that of repairing the loss of an entire ear, whether congenital or otherwise. Several methods have been described. Many surgeons in the past decade have devised methods for improvement in the cosmetic appearance of the appendage; however, they all leave much to be desired in so far as a perfect ear is concerned The requirements of such operations are threefold: first, the shape and size of the ear must correspond to that of the opposite side; second, the skin over the ear should be as near as possible the same texture as that of the adjacent skin of the face; and third, the appendage must have support which should conform as nearly as possible with the continuity of the normal ear. The simplest procedure is to begin by elevating a semicircular flap at the location of the new ear which is approximately one-third larger than that of the normal ear on the opposite side. At the first operation this flap is undermined and the cartilage necessary for support of the ear is placed under it (Fig. 276, *A*). This cartilage is obtained from the fusion of the lower border of the seventh through the ninth rib cartilages. The cartilage is used in one piece in the shape of a question mark, not over 1 mm. thick. The width is that which is desired to conform with the width of the normal ear The edge of the flap, following insertion of the cartilage, is resutured and the cartilage is left embedded for not less than eight weeks. After this the flap is again elevated along with the cartilage implant. Using a split thickness graft from the inner surface of the arm, the entire posterior surface of the flap and the raw surface over the site from which the flap is elevated are covered (Fig. 276, *B*). Following healing it will be noted that the patient has a semirigid flap that protrudes from the side of the head with an outline of the general shape of the ear The next step is the formation of the helix of the ear. This is obtained by making a tube pedicle from the side of the neck which has its base at the tip of the mastoid process and extends down over the surface of the sternocleidomastoid muscle to the clavicle. The tube should be as small in circumference as possible but still large enough to maintain its blood supply. The best rule to follow is to have the tube six times as long as it is wide. After ten days the blood supply can be increased from its upper end by intermittent constriction of the distal end of the tube, beginning with thirty seconds every half hour the first day and doubling this time each day until at the end of five or six days the tube can be continually

constricted at its lower end and the blood supply will be adequate. The distal end of this tube is severed and brought to the upper anterior edge of the flap (Fig. 276, *C*). The tube may be opened for about 0.5 cm. and attached at the upper edge for this distance. It is not advisable at this time to open the tube further, as the blood supply will be embarrassed in the distal part and slough may occur. After two weeks the tube may be opened further and sutured to the remainder of the outer rim of the ear by uniting the tube to the skin of the anterior and posterior sides of the flap (Fig. 276, *D*). After ten days the base of the flap can be severed and the remainder of the tube united if necessary to form the lobule of the ear.

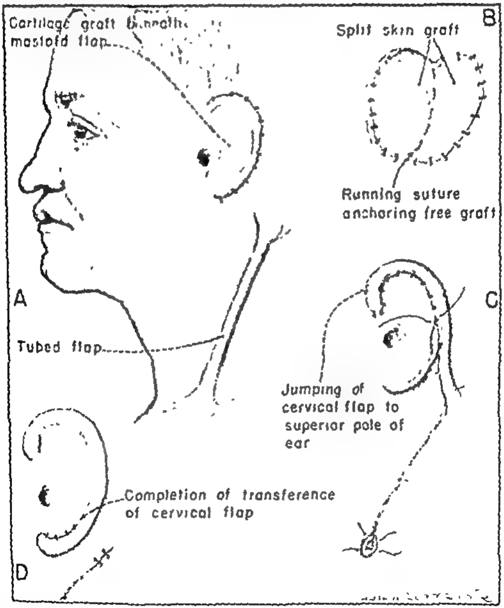


Fig 276 —Reconstruction of entire ear.

The result at this time has the appearance of an ear except there is no shape to the mid portion of the flap corresponding to the concha. This can be acquired by first removing a rectangular piece of rib cartilage corresponding in length and width to that of the depth and circumference of the normal concha on the opposite side. An incision is then made in the posterior fold of the ear. The cartilage is embedded beneath the anterior skin in an upright curved manner after the edges

have been tapered off. The posterior skin is closed over the graft. Other contour irregularities may be corrected at a later date, if desired.

The resulting ear, whereas not entirely the same as the normal ear, will have the general shape and contour and will give an acceptable appearance. The above method described has as its main attribute simplicity of execution. The end results, even though there is still much to be desired, measure up to those obtained by a more detailed, time-consuming technic.

CONGENITAL DEFORMITIES

Some children are born with accessory appendages just anterior to the ear. These are usually the result of malformations occurring following closure of facial clefts. They may be found anywhere from the tragus to the outer corner of the mouth. These consist of small irregular pieces of cartilage, skin, and fat. They have no particular significance but they continue to grow and if not removed present a cosmetic problem. The eradication is simply by excising the excessive skin, fat, and cartilage. If a small piece of cartilage is left, it will grow and form another nodule.

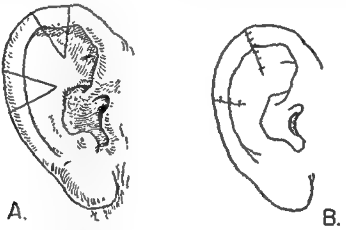


Fig. 277.—Excision of wedge to reduce the size of the auricle.

Two major congenital deformities of the ear which frequently present themselves for correction are inequality and protrusion of one or both ears. Excessive hypertrophy of an ear may be corrected by removing multiple wedge-shaped portions of the entire ear thickness, thus reducing its size to that approaching normalcy. If more than 1 cm. has to be removed, it is best to remove two or more smaller wedges. The wedge is started at the rim of the helix and extended in a triangular fashion through the scapha (Fig. 277.) The cartilage is sutured together with interrupted 000 chromic catgut and the skin on the anterior and posterior surfaces is closed with interrupted sutures of fine silk.

Many technics have been presented for the correction of protruding ears. This deformity may be simply and adequately corrected by excising the cartilage around the antihelix. The operation is carried out by making an elliptical incision with the skin approximately 0.5 cm wide extending around the entire posterior circumference of the ear, exposing the antihelix. (Fig. 278.) The subcutaneous tissue is removed from the fold and an elliptical incision is made through the cartilage approximately 2 mm. around the entire antihelix. Care should be taken not to injure the subcutaneous tissue beneath the anterior skin of the ear. It will be noticed that

the ear can be carried posteriorly, but often the upper half of the ear will still bend outward. This is corrected by removing a triangular piece of cartilage extending for the entire width of the scapha with its base at the antihelix about [illegible] mm. wide, and the apex at the helix. If this triangle is made in the mid portion of the upper ear, it can be folded backward and upward by approximating the edges of the cartilage at the base of the triangle. The posterior perichondrium at the cut edges is sutured together with interrupted four 0 chromic catgut sutures. The sutures are placed parallel to the line of incision so that when tied the edges of the cartilage

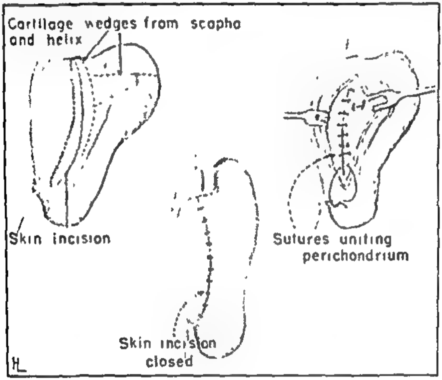


Fig 278 —Operation for correction of protruding ears.

are everted. The skin of the ear is closed with continuous fine silk. No external pressure is necessary to maintain this position and a simple dressing to prevent trauma is all that is needed. All sutures are removed at the end of one week, and care should be taken not to pull on the ears for three weeks, following which time no further precautions are necessary

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CHAPTER 22

THE SALIVARY GLANDS; BENIGN TUMORS OF THE FACE

HARRY J. WARTHEN, JR.

ANATOMY OF THE PAROTID GLAND

McWhorter, who has made a careful study of the parotid gland, describes a large superficial lobe and a much smaller deep lobe. These lobes, he states, are connected by an isthmus, usually made up of gland tissue, which is not located at the upper margin of the gland, as had previously been thought, but about the junction of the upper third with the middle third of the superficial lobe. The facial nerve passes somewhat downward and forward below the external auditory canal, beneath the posterior border of the superficial lobe, then between the superficial and deep lobes, dividing into its various branches during its passage beneath the superficial lobe. The temporofacial division passes above, and the cervicofacial division beneath, the isthmus of the gland. McWhorter states that occasionally some of the branches of the nerve are imbedded in grooves on the surfaces of the lobes but that the nerve is rarely found actually passing through gland tissue.

McCormack and associates on the basis of painstaking dissections demonstrated anastomoses of the temporofacial and cervicofacial divisions of the facial nerve anterior to the parotid isthmus. These connections probably explain the return of function when one of the primary divisions has been severed.

OPERATIONS FOR SALIVARY FISTULA

Despite the difficulty encountered in suturing a divided parotid duct (Christafferson, Ajalat, and Gradman in 1943 stated that they were able to find only five successful repairs reported) an effort should be made immediately to reestablish the continuity of all severed ducts. Seeley states that it is practicable to explore, isolate, resect, and anastomose the duct by primary suture. A dowel of nonabsorbable material such as No. 30 alloy steel wire or horsehair threaded through the normal opening serves as a splint, and the duct should be accurately sutured with fine cotton or silk. The splint is withdrawn from the duct after seven to ten days. The facial nerve is frequently severed in injuries to this region and this should be sutured at the same time. Bailey and Skaff emphasize the importance of preserving the papilla and thread the divided duct on heavy cotton or silk immobilized by lead shot attached to the thread within the mouth and on the cheek near the lateral border of the gland.

If the divided Steno's duct is not seen until late, an external fistula may be present. A large amount of saliva flowing from the fistula during mastication is a source of great annoyance. If the fistula is in Steno's duct, it may be corrected by the operation of Deguise. A silver wire is threaded in a curved needle, which is passed from the external fistulous opening through into the cavity of the mouth. *The external end of the wire is threaded* on another needle and also passed through the external opening so as to enter the mouth at a distance of about 3 mm. from the point of emergence of the other end of the wire. The two ends of the wire are drawn snugly, twisted, and cut short. The skin is excised around the fistula, undercut, and the margins are sutured with fine silk or horsehair, thus burying the remainder of the tract. (Fig. 279.) *The wire can be left in place for several weeks until the skin wound has healed firmly.* In the meantime, the mouth should be kept scrupulously clean.

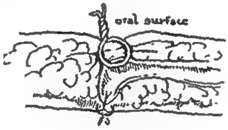

Fig. 279.—Method of Deguise for closing salivary fistula of Steno's duct.

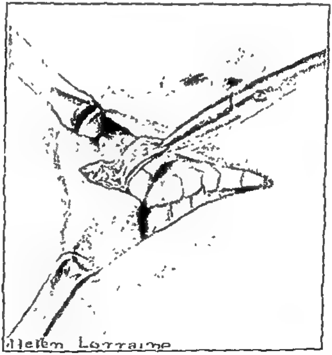

Fig 280—The pedicle of a flap of mucosa is formed from within the mouth

If the fistula is from the substance of the gland itself, a different type of procedure is necessary, the operation of Crouse is probably the most satisfactory. An *incision about 3 cm long is made through the skin and fat,* straight downward from a point about 2.5 cm. below the zygoma and about 5 cm. in front of the ear. Care should be taken to avoid injury to the nerves and blood vessels. The fascial

covering of the parotid gland is exposed and an incision about 1.5 cm. long is made into it, extending into its substance. The lip on the same side is grasped with gauze and the cheek is turned out to expose the mucosa. A flap of mucosa about [illegible] mm. wide, and thick enough to be viable, is formed from near the inner border of the lip back to a point just behind the level of the second upper molar tooth, the pedicle of the flap being situated posteriorly (Fig. 280). A closed curved hemostat is introduced through the external incision, passed forward close to the surface of the masseter muscles, and forced into the mouth just in front of the pedicle mucosa (Fig. 281). The hemostat is opened to dilate the tunnel, and the end of the flap is

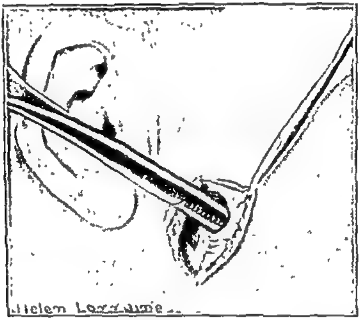

Fig. 281.—Operation of Crouse for closure of salivary fistula of the parotid. The first incision has been made and a tunnel is being made for the strip of mucous membrane.

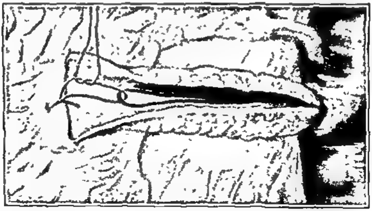

Fig. 282.—The pedicle of mucosa with its base posteriorly has been brought through the tunnel and is fastened into the parotid gland. A double strand of chromic catgut has been drawn through the tract.

grasped, pulled through the tunnel, and fastened to the posterior edge of the incision into the fascia of the parotid gland with a fine chromic catgut suture. The suture is passed like the Lembert intestinal suture to tuck the end of the mucosa under the incised parotid fascia. The ends of this suture are left long. A small clamp is then passed into the external wound and through the tunnel into the mouth, the middle of

a strand of chromic catgut is grasped, pulled through the wound, and tied with the long ends of the fine catgut suture. (Fig. 282.) The ends of the stout chromic catgut are left projecting into the mouth, and the flap of mucosa assumes a tubular shape around them. The external wound is closed in the usual manner.

OPERATIONS FOR BENIGN PAROTID TUMORS

Parotid tumors may be small, round, and rather movable, or may be of a malignant, infiltrating nature.

The tumors should not be treated by x-ray and they should be operated upon when first discovered without any delay to permit the tumor to "ripen." About 2 per cent of these tumors will undergo malignant change if permitted to remain Blair, Moore, and Byars have described an operation which is suitable for benign tumors of the parotid. They state that the tumor and its enclosing gland tissue should be removed en bloc if possible and that all available nearby gland should be excised from between the divisions of the facial nerve.

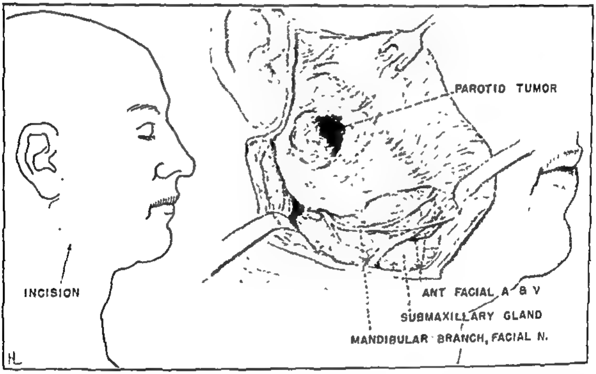

Fig 283.—Incision for excision of benign parotid tumor. The skin flaps are reflected and the dissection is kept in the subcutaneous tissue of the face. The lowest branch of the facial nerve has been located preparatory to dissecting it back to the trunk. (Modified from Blair, Moore, and Byars.)

General anesthesia is administered preferably through an endotracheal tube. The involved half of the face is draped in order that twitching of the facial muscles may be observed. The incision extends from just anterior to the upper attachment of the ear downward in the ear to the lobe. Here it is carried backward for about 1 5 cm then it is directed forward on the neck in a normal skin fold beneath the mandible The skin flap is dissected forward, exposing the entire tumor and parotid gland area The dissection is kept in the subcutaneous tissues. (Fig 283)

The most inferior branch of the facial nerve, the inframandibular division, is then identified. This nerve emerges from the lower pole of the parotid, continues forward in the platysma, below the mandible, and then, coursing upward, it crosses

the mandible near the facial artery on its way to innervate the lower lip. Usually this branch is soon located, although several areas may have to be examined before it is found. Twitching of the lower lip may give the first clue to its location. (Fig. 284.)

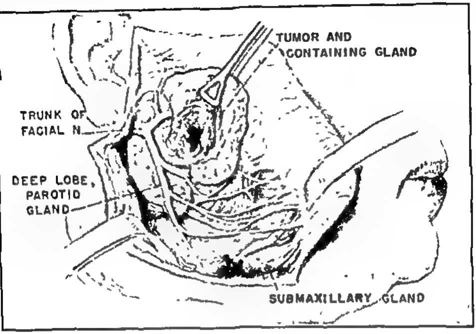

Fig. 284.—The trunk of the facial nerve has been located and the overlying tumor and containing gland have been reflected from the nerve and its branches as they come into view. (Modified from Blair, Moore, and Byars.)

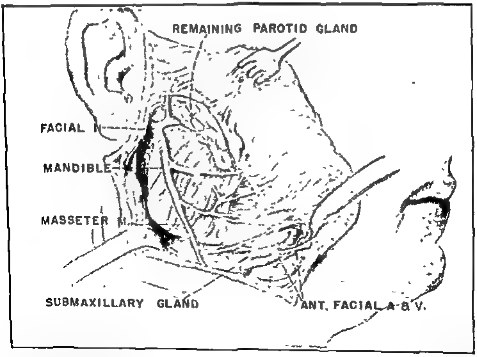

Fig. 285.—The tumor and its containing gland have been removed. The deep portion of the gland adjacent to the tumor has been dissected from between the branches of the nerve. (Modified from Blair, Moore, and Byars.)

Having been found, the branch is traced back to the trunk of the facial nerve. A small mosquito forceps may be inserted along the tunnel containing the nerve, and the overlying tissue is then cut away. The relationship of tumor to nerve is un-

predictable. A superficial tumor may have the radicles of the nerve stretched over its surface, while a more deeply situated tumor may have depressed the nerve into the gland. When the lowest branch is exposed, all parotid tissue superficial and inferior to it may be freely incised and elevated.

After the trunk of the nerve is located, the dissection is continued upward, displaying each of its branches as it is given off. This necessitates dissection within gland tissue and may require separation of the tumor capsule from the nerve fibers on one of its surfaces. If the tumor is superficial to the nerve, it is removed with the gland mass superficial to the nerves, and then as much gland as can be secured from the deeper portion of the gland between the nerve divisions is removed. (Fig. 285.) If the tumor lies deep to the nerve, all overlying gland is removed and the tumor and deeper gland are dissected from between the nerve branches. This technic permits a wide removal of tumor and adjacent gland without danger to the nerve, for its location is known at all times. The bleeding is checked, the incision is flushed out with warm saline, and after a plastic closure a pressure dressing is applied.

Papillary cystadenoma lymphomatosum, a curious embryologic remnant, is occasionally encountered in the parotid gland. These cysts are benign and usually are readily enucleated.

In large mixed tumors and those in which the tumor appears to have broken through the capsule, Adson and Ott recommend the complete excision of the parotid gland with preservation of the facial nerve. Their method obviously would not be applicable to malignant tumors of the gland with involvement of the entire glandular structure or to cases in which the facial nerve is already involved. They advise an incision which starts 3 cm posterior to the tip of the mastoid process and extends downward and forward about 2.5 cm. below the lower border of the mandible to about 4 cm. in front of the angle of the jaw. Another incision is started just in front of the ear at the level of the zygoma and is carried downward immediately in front of the ear to the lower border of the lobe of the ear, where it is curved backward to join the original incision at approximately a right angle. The inframandibular branch of the facial nerve is first exposed through the original incision below the lower border of the mandible, as outlined above. This nerve is carefully traced backward and upward to the point where it joins the larger branches of the facial nerve beneath the posteroinferior portion of the parotid gland. The perpendicular incision is then deepened, care being taken to stay very close to the anterior portion of the ear, until the posterior border of the masseter muscle and the mandible are exposed. Special care must be exercised during this portion of the dissection to avoid injury to the branches of the facial nerve. When this part of the operative field has been connected with the field exposed by the original incision, and the branches of the facial nerve are exposed and identified, these branches are dissected away from the parotid gland, the dissection being carried from behind forward, and the nerve fibers are handled as gently as possible.

The nerve, as a rule, is found surrounded by gland substance for only a short distance, and the branches of the nerve then lie directly on the surface of the masseter muscle in contact with the inner surface of the superficial lobe of the parotid After the entire superficial lobe has been dissected away, it is removed and any adherent skin is removed with it. The branches of the facial nerve are

then carefully separated from the underlying small deep lobe of the parotid and, while these branches are gently retracted, the remaining deeper portion of the parotid gland is removed. Especial care should be used to avoid injury to the temporal artery while the zygomatic portion of the incision is deepened. While these authors do not advise it, it would seem wise, in the larger tumors of the parotid, to expose the external carotid artery and place a ligature around it, in case of injury to one of its larger branches during the removal of the gland. If an appreciable area of skin is removed at the time of removal of the superficial lobe of the gland, it may be necessary to transplant a flap of skin downward from the temporal region so that this defect may be closed completely. This will usually not be necessary, however, as this operation will seldom be applicable to those cases with extensive skin involvement. The skin margins should be approximated with very fine silk. It is wise to insert a small drain for twenty-four to forty-eight hours. A pressure dressing should be applied.

OPERATIONS FOR MALIGNANT TUMORS OF PAROTID

In malignant growths of the parotid, especially those with paralysis of the facial nerve, the entire gland should be excised along with the nerve. The patient should always be warned before operation that a facial paralysis will result on the involved side. It is usually advisable to resect the regional lymph nodes when a malignant growth of the parotid is removed. If this is to be done, the incision for removal of the parotid is modified so as to afford an ample exposure for a block dissection of either the upper portion or the whole side of the neck, depending upon the indications

The incision should be so shaped as to enable the operator to remove the primary tumor and the regional lymphatic-bearing tissue in one block. Usually a straight incision is made from the zygoma just in front of the ear, downward over the anterior border of the sternocleidomastoid muscle. An offset just below the ear will make a late contracture of the scar less likely. If the nodes in the upper triangle of the neck are to be resected at the same time, a transverse incision also is made beneath the border of the jaw to the midline of the neck about 2.5 cm. below the chin The technic of block dissection of the neck is discussed elsewhere.

If the malignant growth in the parotid is attached to the skin, the first incision should be made at a safe distance from this point, and another incision should circumscribe this area in such a manner as not to make contact with the affected tissues The lower end of the incision over the sternocleidomastoid muscle is deepened until the external carotid artery is exposed. This artery is ligated a short distance above the superior thyroid branch It is best to place another ligature on it just above the facial branch, and to tie the facial, the lingual, and posterior occipital branches, if they can be readily exposed. This not only decreases the bleeding, but, on the principle of starvation of malignant growths, as advocated by Dawbarn, it may retard the recurrence of the cancer The edges of the wound are then thoroughly undercut to expose the parotid tumor as fully as possible. The parotid can then be easily enucleated with the cautery by dissecting from before backward. The cautery follows the line of cleavage, lessens the bleeding, destroys adjacent cancer cells, and seals the lymphatics When the temporal vessels are reached, they are doubly clamped and divided. After getting well under the parotid growth

from in front and above, the cautery is carried posteriorly, close to the capsule of the gland but not entering it. The dissection is then carried down to the neck and the external carotid is again clamped and tied just below the parotid, and the parotid gland with the tumor is cut away with the cautery. Care should be taken in this latter step not to injure the internal jugular vein.

If a complete block dissection of the neck is necessary, the incision extends from the zygoma downward over the anterior border of the sternocleidomastoid muscle and terminates in front of the sternoclavicular joint. The dissection is made from below upward, and the parotid gland is dissected out along with the mass of tissues from the neck in the manner just described, and the wound is closed. A drain should be inserted through a stab wound or in the lower angle of the incision, and a pressure dressing is applied.

REMOVAL OF SALIVARY CALCULI

A calculus may occur in the ducts of any of the salivary glands but is more likely to be found in the parotid and submaxillary ducts. Its location may be determined by palpation, but roentgenography is often necessary. When its location is established, it may be removed by cutting through the mucous membrane and medial wall of the duct directly down on the calculus while it is made prominent by pressure from without. It is sometimes necessary to excise the submaxillary gland in order to remove a calculus in the substance of the gland.

TREATMENT OF BENIGN TUMORS OF THE FACE

Tumors of the face are common, especially such benign tumors as papillomas and nevi. They are best removed by an excision which includes a small amount of surrounding healthy tissue. The defect is then repaired by utilizing some of the plastic procedures that have already been described. Accurate scalpel incisions with the long axis parallel to Langer's lines of tension and careful suturing will leave a very inconspicuous scar. Such operations usually are performed with a local anesthetic. The tumor is circumscribed by incisions, diamond-shaped or preferably elliptical, with the growth in the center of the area. The incisions are made with a small sharp knife and are carried through the full thickness of the skin. After the growth is removed, the edges of the skin are undercut, and bleeding is controlled by compression and clamping of the larger vessels with mosquito forceps. Fine plain catgut or cotton is used where ligatures seem necessary. The deeper layers of the skin are brought together with sutures of fine plain catgut or cotton. The skin is united accurately by interrupted sutures of fine silk. (Fig. 286.) A firm, small dressing of dry gauze is kept over the wound for twenty-four to forty-eight hours to protect the incision and to prevent swelling. The sutures are removed in two to four days Concentrated compound tincture of benzoin or collodion may be applied to dry wounds when the sutures are removed. This acts as a protective skin-splint for several days before it peels off. If a local anesthetic is used, it is important to insert the needle in healthy tissue at some distance from the growth so that the infiltrating fluid is always injected toward the lesion and the needle will not pass through involved tissue. In this way neither infection nor malignancy, if suspected, will be spread. It is far safer, however, in dealing with either condition, to use a general anesthetic, preferably Pentothal Sodium intravenously.

Electrodesiccation also has a distinct field of usefulness in the treatment of benign tumors of the face. Verruca and senile warts respond well to coagulation. Hyperkeratoses, if treated early, before the possibility of malignant degeneration has occurred, may also be coagulated. Any question of malignant change should be checked by a biopsy with wide excision or radiation when indicated. Fibromas should be excised surgically while coagulation of xanthomas gives satisfactory results.

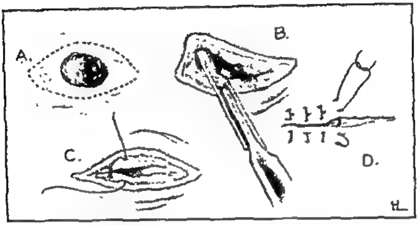

Fig. 286.—*A*, Lines of incision for excision of a benign tumor of face. The long axis of the ellipse should coincide with Langer's line of tension in this area. *B*, The growth has been excised and the skin and subcutaneous tissue are mobilized. *C*, The superficial fascia and fat are approximated with fine sutures of plain catgut, cotton, or silk. *D*, The skin margins are approximated carefully with interrupted on-end mattress sutures of cotton or silk.

TREATMENT OF ANGIOMAS

The successful treatment of all angiomas is based on one of two principles, either excision of the tumor or sclerosis of its vessels (Fig. 287). The size and location of many angiomas make excision unsatisfactory because of the resulting deformity. For this group in which surgical removal is not advisable, there are several methods of producing sclerosis: irradiation with x-ray and radium, application of carbon dioxide snow, actual destruction with the cautery, coagulation in multiple adjacent areas with an endotherm needle, injection of boiling water or sclerosing fluids, as well as other less satisfactory methods.

Irradiation by radium or x-ray must be used carefully and only by one skilled in this particular field. It is most satisfactory on the thin surface hemangiomas, and it is also used frequently in conjunction with other methods. (Figs. 288 and 289) Tattooing is of distinct value in some cases.

The so-called port-wine nevus is best treated by ultraviolet radiation, blistering doses being given once weekly for periods of several months. Occasionally, gradual excision of a port-wine mark or excision with grafting will give good results, depending upon the size and location of the affected skin.

The commonest types of hemangiomas are slightly elevated, lobulated, bluish-red tumors involving the skin and adjacent subcutaneous tissues. They vary greatly in size and location. When excision is inadvisable and expert irradiation therapy is not available, the simplest method of treatment is the use of carbon dioxide snow. This treatment may, like x-ray and radium, be used in conjunction with other methods. The snow is applied directly over the angioma with firm, even pressure

for 5 to 20 seconds. The application is first given for 5 to 10 seconds with slight pressure, and subsequently the pressure and time are increased according to the amount of destruction desired and the results of the previous treatments. *It is best* not to apply the carbon dioxide snow to an area greater than 2 cm. in diameter at one time. In large tumors, however, several such areas may be treated at one time if there is at least 1 cm. of untreated tissue intervening. Applications are repeated in six to eight weeks. The advantage of this method over irradiation and excision is that desirable cosmetic results may be obtained with less experience.

Fig. 287. Fig. 288.

Fig. 287.—Hemangiosarcoma of right cheek and lower eyelid of child three and one-half months old

Fig. 288.—Seven months after excision of lesion with plastic closure and x-ray therapy. There was no evidence of recurrence after nine years.

Fig. 289.—Method of excision and undermining wound remaining after excision of hemangiosarcoma

When the angioma is of the cavernous type, extending into the subcutaneous and deeper tissues and protruding above the skin, and excision seems impractical, coagulation with an endotherm needle or injection of sclerosing fluids gives best results in treating the deeper portions of these tumors.

Figi uses radon seeds in cavernous hemangiomas of the lips and mouth in infants and children, but similar hemangiomas in adults have responded well to electrocoagulation. A sharp-pointed insulated electrode either is inserted directly through the overlying mucous membrane or is carried into it through a minute stab wound in the skin. Intensive coagulation is necessary, for the heat is diffused rapidly by the blood. A finger is held over the area being coagulated to determine the degree of coagulation. The extent of the coagulation is also gauged visually. Figi warns that the margin of safety is narrow between effective coagulation and a dangerous slough.

Plexiform hemangiomas are more difficult to treat because of the arteriovenous factor present, and ligation of entering vessels is often necessary. Figi uses electrocoagulation in tumors showing little pulsation, but combines this with ligation of the afferent vessels in more extensive cases.

A combination of the above methods frequently gives better results than reliance on one agent to the exclusion of others.

EXCISION OF SEBACEOUS CYSTS (WENS)

Sebaceous cysts may be readily removed under local anesthesia. Care must be taken that the exact location of the tumor is determined and marked prior to the local infiltration of the anesthetic solution in order that the location of the cyst may not be obscured by the resulting edema. This is especially necessary in small cysts. An ellipse of skin incorporating the opening of the offending sebaceous gland and situated in such a manner that the long axis of the skin coincides with the normal wrinkles of the part is outlined. The dissection is carried downward and the cyst must be removed in its entirety. If the cyst is ruptured during the dissection, a part of the wall may remain and a recurrence is likely. The defect is closed by buried fine catgut sutures and the skin is approximated with interrupted silk.

Early excision is the method of choice, because if the cyst becomes infected a two-stage procedure will be necessary. Simple incision and drainage must first be carried out, followed by excision of the cyst wall after the infection has subsided.

A somewhat similar method of treatment may be useful in large cysts arising on the face or other exposed part. The conspicuous depression which may follow the primary excision of a large cyst in such a location may be avoided by incising and expressing the sebaceous material as an initial procedure. After the surrounding tissues have adapted themselves to the lessened size of the cyst, the wall may be removed as a secondary procedure with minimal disfigurement.

EXCISION OF DERMOID CYSTS

These congenital inclusion cysts are frequently situated in the midline and often are found at the inner or outer end of the eyebrows. The discovery of a cystic swelling in these locations, unattached to the skin, should be followed by an x-ray of the underlying skull, for dermoid cysts often are associated with defects of the bone which permit the cyst to rest upon the dura. If a punched-out area of bone is present, special care should be taken in the cleanup and operative technic to prevent any likelihood of deep infection. A segment of skin does not have to be removed, for dermoid cysts are not adherent to the overlying skin. Simple excision with care to remove all of the cyst wall, plus a plastic closure of the incision, will effect a cure.

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CHAPTER 23

OPERATIONS FOR CARCINOMA OF THE FLOOR OF THE MOUTH, PALATE, LOWER AND UPPER JAWS

LEROY SMITH

CARCINOMA OF THE FLOOR OF THE MOUTH

Diagnosis

Most carcinomas involving the floor of the mouth arise as extensions from the border of the tongue or alveolar process. The incidence of primary carcinoma in this region is relatively low, comprising about 1.5 per cent of all malignant tumors. Most of the patients are over sixty years of age.

The greater percentage of these growths are poorly differentiated and the spread is rapid. The most frequent site occurs in the anterior half of the mouth and about the openings of the salivary ducts. The first sign is usually a small indurated pea-sized nodule occurring on the mucosa with a central area of red ulceration. This later bleeds easily and, when treated locally with the cautery, appears to improve for a short time, probably because of the improvement of the superimposed infection. Papillary carcinomas are rare and occur mostly along the lateral mucosa of the tongue. In the papillary carcinoma there is always a small, hard area surrounding the base which fixes the lesion to the deeper tissues. This is not true in the benign papilloma.

Carcinomas appearing in the posterior half of the floor of the mouth are usually large and are firmly fixed before superficial ulceration occurs. This may be in some measure caused by the absence of the persistent trauma to which the anterior lesions are subjected.

There is but one way to be assured of the diagnosis of a growth in the floor of the mouth and that is by tissue biopsy. If there is any ulcerative site which does not respond immediately to conservative treatment, an excision biopsy (if the lesion is less than 1 cm. in size) or a small biopsy from the site of the ulcer must be done.

Surgical Treatment

In some clinics all malignancies of the floor of the mouth are considered as amenable only to x-ray therapy. Their reports of five-year cases are none too impressive, and for this reason, except in the far-advanced cases, surgical treatment has its place.

If the tumor is less than 1 cm. in diameter and is superficial, excision with at least 1 cm. margin of clinically normal tissue may be carried out with sharp dissection. The resulting wound is then closed primarily without drainage. In cases where the tumor is 1 cm. or larger, or if a small tumor is deep in the floor tissues, excision with an electrosurgical knife is preferred. This dissection should include not only the tumor but at least 1 cm. of adjacent normal tissue. These wounds are left open and are packed with iodoform gauze for forty-eight to seventy-two hours. Upon removing the packing, the wound is irrigated two to three times daily with saline. Following cautery excision, the nutrition is maintained by liquids and intravenous fluids until the wound heals sufficiently for intake of a normal diet.

The preceding is the surgical approach to malignancies that have no evidence of lymphatic extension. It is our practice not to do neck dissections unless the nodes are actually involved, in which case a different approach to the situation has to be made. After such treatment as local excision, the patient should be kept under weekly surveillance for three to four months to ascertain the presence of local recurrence or metastasis. Should the latter occur, a radical neck dissection is immediately done. It is important to watch both sides of the neck in the case of malignancies occurring in the anterior floor of the mouth. If it is felt at the time of operation that all of the tumor has not been removed, postoperative x-ray is advised immediately following wound healing.

In cases that have lymphatic metastasis, the treatment is much more radical. Dissection of the tumor in the oral cavity is begun, separating it from the surrounding tissues with an electrosurgical cautery. The base of the growth is left undisturbed and a radical neck dissection is done. It is important to begin the dissection at the clavicle and work upward. When the floor of the mouth is reached, the entire mylohyoid muscle is removed along with the tumor. This enables one to excise the growth with the lymph chains and glands in one block without cutting across any involved tissue. If the tumor is attached to the mandible, a section of this bone is removed through its entire thickness at the point of attachment. In cases that show evidence of tongue invasion, a hemiglossectomy is also carried out. All cases with lymphatic metastasis should receive postoperative x-ray treatment to the involved side.

In recurrent malignancies of the mouth and neck, surgery offers little benefit following radical operation, and either x-ray or radium will control the growth more effectively.

The over-all prognosis in carcinoma of the floor of the mouth is only fair. In lesions of lower grades without metastasis, occurring in the anterior half of the mouth, a cure is more promising. In high grade cases and those that show lymphatic extension, the prognosis is poor.

CARCINOMA OF THE PALATE

Diagnosis

Carcinomas of the palate are rare, accounting for only about 2 per cent of intraoral carcinomas. They are seen more often in patients of advanced age and more frequently in males. Because of the anatomical difference between the anterior and posterior parts, the treatment and prognosis are different. Malignant growths in the hard palate are less frequent and are seen as superficial ulcerations

which are slow-growing, red, and surrounded by a slightly raised edge. The two predisposing factors seem to be chronic irritation from dentures and leukoplakia. Because of their slow growth and the infrequency of metastasis, the prognosis is fairly good with either x-ray treatment or surgical removal. When the bone is invaded, spread to the nasal mucous membrane is rapid and the prognosis then becomes very poor.

Growths originating in the soft palate begin usually just medial to the tonsil. Ulceration is late, but when it occurs it gives rise to pain and difficulty in swallowing. These tumors are high grade and metastasize rapidly. This site does not lend itself to surgical management as well as does the anterior palate. For this reason better results have been obtained by the use of radium and x-ray therapy than by surgical removal. In those instances where lymphatic extension is not present, surgical eradication is sometimes used with good results. In selected cases where the lesion is small and the metastatic nodes are few, surgery followed by postoperative x-ray may be considered. Diagnosis should be made in all cases by biopsy of the tumor. Biopsy by surgical removal of a portion of the tissue under suspicion is preferred to the aspiration technic.

Surgical Treatment

Malignancies arising in the hard palate are removed by the electric cautery. A wide margin of normal mucosa is included and all bleeding is controlled by electric coagulation. In the use of the cautery, one should expect to lose that portion of bone which is adjacent to the tumor, although the inferior table is usually the only part affected. If the growth is old or if it is extensive, bone invasion is to be suspected. Involvement of the nasal mucosa over the area is considered to be a contraindication to surgery. X-ray therapy is more effective in these advanced cases.

As has been stated, lesions of the soft palate are usually not controlled by surgery, but where the area of involvement is small and the growth is not over a few weeks old symptomatically, surgery may be used. Simple excision either with a knife or electric cautery is never indicated. A radical removal is necessary if surgery is used. This should include the entire soft palate on the involved side and at least three-fourths of the opposite side, and, if the lesion is in or near the midline, a total resection of the soft palate must be done. Laterally the tonsillar pillars and tonsillar fossae should be removed, the dissection stopping at the posterior floor of the mouth. This dissection is done preferably with the electric cautery. In such instances the patient should be advised of the symptoms and sequelae following the operation.

Soft palate malignancies having early metastasis may be treated by an intraoral operation, as described above, followed by a complete block dissection of the lymphatics of the neck on the side of involvement.

Surgery has no place in recurrence following x-ray or surgery. At present, treatment of these cases with radium or x-ray is all that one can offer.

Reconstruction of the palate defect can be carried out by prosthetic appliances. After an elapse of three months without evidence of recurrence, a plastic denture can be placed over the anterior palate which extends posteriorly to fill the opening left after soft palate removal. This will afford the patient relief in retaining food and drink within the oral cavity and will also improve the speech.

MALIGNANCY OF THE MANDIBLE

Diagnosis

Malignancies occur in the lower jaw or mandible about five to one over those in the maxilla, and approximately 75 per cent of these are metastatic in origin. Almost any epithelial malignancy occurring anywhere in the body can be carried by the blood stream *and give rise to secondary growths in this bone. In addition* to these, invasion of the bone from nodes adjacent *to it are frequent. Primary new* growths are fortunately rare, and the most frequently seen among these are malignancies such as adamantinoma, periosteal osteogenic sarcoma, endosteal osteogenic sarcoma, and periosteal and endosteal fibrosarcoma.

Secondary invasion should always be suspected in a mass located in the mandible producing bone destruction following diagnosis of carcinoma elsewhere in the body, particularly in the oral cavity. There is usually a difference in the x-ray findings between blood stream metastasis and direct extension. In the former, bone destruction is circumscribed, frequently producing a punched-out appearance. In the latter, there is a moth-eaten appearance which is irregular in outline adjacent to the external tumor.

*Primary malignant lesions of sarcomatous origin are frequently hard to differen*tiate from blood stream metastasis. The one characteristic in the osteogenic tumors is the evidence of bone production throughout the area involved. Various benign lesions, namely, dentigerous cysts, composite adenomas, and connective tissue adenomas, appear frequently on x-ray examination like malignant tumors. The clinical evaluation as to time, symptoms, and behavior of the growth on repeated x-ray studies will aid in the differentiation.

Malignancies occurring in the lower jawbone are rapid in growth and relatively early, giving rise to pain about the teeth or over the course of the mandibular nerve. *Early positive diagnosis can be secured only by tissue biopsy, which should* be done at a time when preparation has been made to remove the lesion if malignancy is found.

Treatment

The only satisfactory treatment for cure of malignant tumors of the lower jaw *is removal of the involved portion of the mandible The external approach is best* in that better exposure can be obtained and any involved nodes can be included in the dissection. If the lesion is confined to the bone and in the arch of the mandible, then only the involved part plus 2 cm. of normal bone on each side of the lesion is taken. On the other hand, when the growth has *involved the soft tissues or occurs* in the ramus, the entire half of the jaw is removed.

The technic for removal of half of the mandible is as follows. An incision is made in the skin beginning slightly behind the angle of the jaw and extending along the inferior border until the midline is reached. The subcutaneous tissue is incised down to the bone and the external maxillary artery and vein are clamped and divided. A curved clamp is passed beneath the bone in the midline through the raphe of the mylohyoid muscle into the oral cavity, piercing the mucosa at the gingival fold. A Gigli saw is then passed through this tract and the bone is sawed through (Fig. 290). Bleeding is controlled by packing the wound with dry gauze.

The external skin and subcutaneous tissues, including the masseter muscle, are dissected from the lateral surface of the mandible and rotated upward until the buccal mucosa is seen. This is then incised and the incision is carried posteriorly to the ramus. The severed end of the bones is grasped with forceps and pulled downward and outward, exposing the medial attachment of muscles and mucous membrane. These are cut from the mandible, allowing the entire ramus to come into view. The attachments to the coronoid process are severed and the condyle is liberated from its capsule by an encircling incision. Extraction of the entire bone can now be accomplished. The wound is closed in layers, using 000 silk sutures. A rubber tissue drain is inserted into the lower angle of the wound. The opposite side of the jaw should be wired to the upper jaw by interrupted wires of steel. In those cases in which a section is to be removed, the above exposure over the part to be extracted is carried out. The section of bone is cut with the Gigli saw at each end as described above. The soft tissues are dissected off of the bone on the outer and inner sides, including the mucosa. The wound is closed in layers with sutures of 000 silk. The two halves of the mandible are wired to the upper jaw by passing wires between the upper and lower teeth. If teeth are not present, bone plates of stainless steel are used across the gap and secured to each end with screws to assure the maintenance of position.

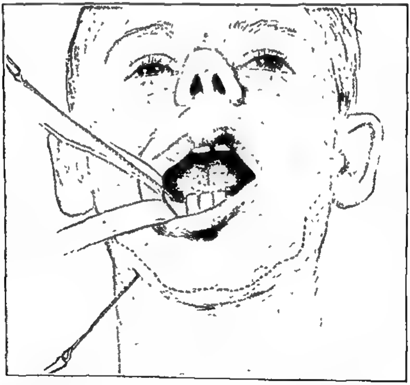

Fig. 290.—Division of the mandible with Gigli saw passing through a small external incision in the skin overlying the inferior border of the mandible and the incision in the mucous membrane of the alveolar process.

Repair of the Mandible

Following resection of the mandible for malignant growths, repair is not advised under three months. This period allows time for good healing of the wound and also for the presentation of any recurrence.

The reconstruction of half of the mandible is executed by the implantation of a bone graft reaching from the cut end of the bone to the temporomandibular fossa. The graft may be from either a rib or the iliac crest. The latter is preferred. The old incision is opened throughout its medial half. Care is exercised not to perforate the mucosa and enter the oral cavity. By sharp dissection a tunnel is made through the posterior half of the old incision until the fossa is reached. All bleeding is controlled by packing. The end of the intact mandibular remnant is exposed, and the end is freshened by removing all new growth. The site is now ready to receive the graft. An incision is made over the opposite iliac crest, extending from the anterior-superior spine backward for 15 cm. The periosteum is removed from both sides, including the insertion of the muscles over the anterior rim. With a small chisel the entire curve of the crest is removed and the wound is closed in layers, using 0 chromic catgut for the fascia and 000 silk for the skin. It will be found that the curvature of the graft will fit the approximate contour of the recipient site. The end chosen to enter the fossa is rounded to a suitable size and inserted through the opening. The excessive medial end is cut to overlap the end of the mandible for a distance of 2 cm. Using a small bone-cutting forceps, the opposing surfaces are flattened to fit securely in apposition with one another. A hole

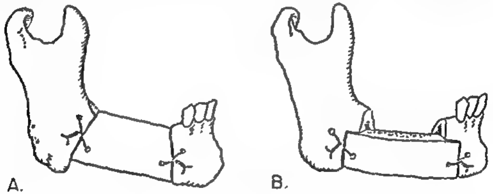

Fig. 291.—Fixation of bone graft to the mandible by wiring.

is made through this union and the two sides are held together with a wire ligature (Fig. 291) passed through the hole and around both bones. The subcutaneous tissue is united snugly over the graft and sutured with 0 plain catgut. The skin is closed with interrupted four 0 silk sutures. Fixation is secured by wiring the upper and lower teeth together. X-rays are taken to show position, and the fixation is maintained for eight to twelve weeks until firm union has taken place. The repair of a portion of the arch that has been removed is performed by incising the scar of the first operation and exposing the two cut ends of bone. These are freshened by amputating the healed ends, exposing the medullary cavity. Exposure of the oral cavity should be carefully avoided. Into this recipient bed, a rib, a piece of tibia, or bone chips may be placed as a graft. The most satisfactory is a graft from the anterior-superior surface of the tibia. The entire length, width, and cortical thickness can be estimated and removed through an incision made in the skin over the anterior tibia. The bone is removed with saw or chisel and the periosteum is left on; although it is not absolutely necessary for healing, it does hasten it. This graft is placed between the two ends of the exposed mandible, overlapping each for 2 cm. A hole is made in the center of each overlap and a piece of steel wire or fascia is passed through it and tied around the bone ends. The subcutaneous

tissue is then closed securely over the bone with 0 plain catgut and the skin is closed with mattress sutures of four ■ silk. The jaws are wired in apposition, as described, and left for eight to twelve weeks.

MAXILLA

Tumors occurring in the upper jaw are the same type that have been described in the mandible. The maxillary bone is also subject to metastasis from the antra and palate by direct extension. Although the x-ray may show bone destruction, the proof lies wholly upon tissue biopsy.

If a growth is limited to the alveolar process, it may be removed by first cutting the mucosa and stripping it back to the point at which the section of the bone is to be made and then removing the bone by a small sharp chisel or finger saw. Schlange's method is to drive several gouges in the proposed line of resection of the alveolus and leave them in position to control hemorrhage until the last gouge is driven in to complete the separation, when the wound is quickly packed. If a solution of epinephrine is injected into the mucosa before the incision is made, the bleeding will be greatly diminished and the operation facilitated.

Excision of the superior maxilla may be done for malignant tumors. A number of incisions have been devised, as it was a standard operation of preantiseptic days. Probably the most satisfactory incision is that of Fergusson, which begins at the inner canthus of the eye, goes downward in the groove between the nose and cheek, skirts the ala of the nose, curves inward to the midline of the upper lip, and divides the upper lip vertically (Fig. 292). The upper end of the incision is extended laterally along the lower margin of the orbit. The flap is reflected outward and the maxilla is exposed. Unless the indications of the operation demand it, it is best to leave the orbital plate of the maxilla, but if this cannot be preserved safely, the periosteum should be stripped up and the orbital contents lifted gently upward and outward with a retractor. The malar bone is divided with forceps or a Gigli saw, and the nasal and orbital processes of the maxilla are sectioned at the inner and lower portion of the orbit. The mouth is opened and an incision is made in the hard palate along the midline or parallel to it. The central incisor teeth are removed, and with a finger saw the hard palate and alveolar process are divided from within the nostril, and the soft palate is separated from the hard palate with scissors The maxilla is then seized with heavy forceps, bent outward, and removed by a twisting motion, any attached strands of tissue being cut. The cavity caused by its removal is at once packed with dry gauze, which is pressed firmly in position, held for four or five minutes, and then carefully removed. Bleeding points are clamped and ligated. The wound is packed with iodoform gauze and the reflected flap is sutured into position. Preliminary ligation of the external carotid artery and its branches lessens bleeding and may decrease the chances of recurrence.

The patient is put to bed with the head toward the operated side and the mouth is kept clean by irrigations, the patient being turned in such ■ position that the fluid readily runs out.

If the growth in the upper jaw involves the skin, the incision of Fergusson is not satisfactory. An incision applicable for this type of case was devised by Binnie, who recommended that an incision be made around the tumor in healthy skin as close to the growth as is thought wise. The upper junction of these incisions

Fig. 292.—Lines of incision for excision of the upper jaw. (Fergusson.)

Fig. 293

Fig. 294

Fig. 293.—Lines of incision for excision of the upper jaw when the skin is involved. (Binnie.)

Fig. 294.—Reflection of flap for excision of upper jaw. (Binnie.)

is joined by another incision that begins at the nose just below the inner angle of the eye and the lower junction is extended almost to the angle of the mouth (Fig. 293). The flap, with the nose and upper lip as its base, is dissected up and reflected inward, and the incisions around the growth are undercut and retracted outward (Fig. 294). The bone is then removed in the manner described by Fergusson.

When squamous cell cancer involves the orbit and the upper jaw, a typical operation frequently cannot be done. The growth should first be cauterized thoroughly with a thermocautery and circumscribed with an incision at a safe distance from its origin. Dissection is made to remove the neoplasm and the tissues immediately around it in one mass as far as possible. The remaining raw surface should then be thoroughly cauterized and a suitable plastic operation may be undertaken at some later time.

A temporary osteoplastic resection of the superior maxilla to gain access to a tumor in the nasopharynx can be done in much the same manner as indicated in the Fergusson operation except that the maxilla is left attached to the flap and is reflected along with it. After the operation has been completed, the flap with its attached bone is replaced. In this operation it is not necessary to remove the lower plate of the orbit, which is separated from the rest of the maxilla by a sharp chisel. When a cancer of the upper jaw involves the cheek, the lymphatic nodes on that side of the neck should be removed later, and this dissection should include the submaxillary, parotid, and superior deep cervical groups of nodes. *Irradiation* has largely replaced surgery in the treatment of malignant lesions of the jaws, especially those involving the upper jaw. However, involved regional lymphatic nodes should be radically excised.

Repair of Maxilla

Following operations for removal of tumors of the maxilla, the defect is mainly one of cosmetic concern. Functionally, the patient is able to speak and eat adequately, provided the major part of the palate is left. The soft tissues will become adherent to the bony defect, giving a concave appearance to the cheek. Elevation of the soft tissues by an intraoral approach followed by split skin lining of the pocket will enable restoration of contour by the placing into it of a plastic shell attached to a removable dental plate. This method is satisfactory only in select cases. Other methods of restoring contour make use of the implantation of fat grafts, cancellous bone grafts, and tantalum plates. If these are to be used, an external approach should be made. The technic is described in Chapter 18.

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CHAPTER 24

OPERATIONS ON THE TONGUE, LIPS, AND CHEEKS

HARRY J. WARTHEN, JR.

ANATOMY OF THE TONGUE

The tongue is made up of two groups of muscles, intrinsic and extrinsic, the latter being of more interest to the surgeon. The intrinsic muscles are inserted into the median raphe, with a definite plane of cleavage between the two halves of the tongue at that point. The extrinsic muscles are: (a) the geniohyoglossi, flat and triangular, which extend from the posterior surface of the mandible on either side of the symphysis to the hyoid bone and to the tongue, reaching the dorsum of the tongue near the median raphe; (b) the hyoglossi, which extend from the hyoid bone upward to the tongue; (c) the mylohyoids, which, while not forming a part of the tongue, play a considerable part in its movements, for they help to control the position of the hyoid bone; (d) the styloglossi; and (e) the palatoglossi muscles, which connect the tongue with the soft palate through the anterior pillars of the fauces.

The entire blood supply to the anterior portion of the tongue comes from the lingual arteries, but the posterior portion, behind the circumvallate papillae, receives a part of its blood supply from the pharyngeal vessels. The circulation of the two sides of the tongue is relatively separate, very few vessels crossing the median raphe, the central fibrous septum which is fixed to the hyoid bone. The lingual arteries are located a little nearer the ventral than the dorsal surface and slightly nearer the midline than the lateral border. The ranine veins pass from the tip of the tongue posteriorly, ventral to the arteries.

The tongue has a rich lymphatic supply with free anastomosis across the median raphe. This is true especially of that portion adjacent to the median raphe, or approximately the middle third. Most of these lymphatic vessels drain into the upper carotid lymphatic nodes of the deep cervical chains, one node in particular, the so-called chief node, situated at the bifurcation of the common carotid artery, receiving an unusually large number of vessels from the tongue. The lymphatics from the margin and, to a lesser extent, from the median part of the tongue drain into the submaxillary lymph nodes and occasionally into the sublingual nodes, while those of the anterior portion of the tongue empty into the anterior deep cervical nodes below the level of the omohyoid muscles. Because of this free anastomosis between the lymphatic vessels of the two sides, a lesion on one side of the tongue will frequently metastasize to the nodes of the opposite side of the neck.

The hypoglossal nerves furnish the chief motor supply to the tongue and the lingual branches of the fifth cranial nerves supply ordinary sensations to its an-

terior two-thirds. The chorda tympani nerves give the sense of taste to its anterior two-thirds, while practically all sensation including taste is supplied to its posterior third by the glossopharyngeal nerves.

OPERATIONS ON THE TONGUE FOR BENIGN TUMORS

In operations on the tongue a general anesthetic administered through an endotracheal tube with the pharynx packed off to prevent entrance of blood is of great aid. Pentothal Sodium intravenously is of especial value in oral surgery. This may be supplemented by an inhalation anesthetic or oxygen through the endotracheal tube. If a cautery is going to be used during the operation, a noninflammable anesthetic must be used.

While the removal of benign tumors of the tongue follows the same general principles of operative surgery applicable to the removal of benign tumors elsewhere, there are special considerations because of the function of the tongue. In macroglossia whether from muscular or lymphatic hypertrophy, operation may be indicated. The size may be reduced by excision of sections along the margins. The tongue is pulled forward by a suture near its middle and an incision is made on its dorsal surface parallel to and as far from its lateral edge as seems necessary to include a sufficient amount of tissue. A corresponding incision is made on the undersurface of the tongue so that a wedge-shaped area is excised. Traction is used to control bleeding and to obtain a better exposure. The wedge-shaped area is removed from behind forward, rounding the tip of the tongue, and the same procedure is then carried out on the opposite side of the organ Sutures are inserted as the tissue is excised. Every effort should be made to give the tongue as normal an appearance as possible. Sutures of fine silver are satisfactory for such wounds and may be twisted so as to prevent the ends from irritating the oral mucosa. Silver wire has advantages as suture material in this region in that it is only slightly irritating, is mildly antiseptic, and, therefore, may be left longer than other sutures. Silk may also be used for closure of defects of the tongue. Because of the great mobility of the tongue, sutures should remain longer than in other regions and, if the wound is extensive, all of them should not be removed at the same time Special care must be taken to maintain an adequate airway postoperatively, and antibiotics should be given

Cavernous hemangiomas of the tongue and oral cavity are seen occasionally. Figi has obtained good results in infants and children by the use of radon seeds, but he states that electrocoagulation is more satisfactory in adults. He uses a sharp-pointed, insulated electrode which may be introduced through a minute stab wound at a distance Plexiform hemangiomas with arteriovenous communications may require extensive preliminary arterial ligations.

Benign localized tumors may be removed by V-shaped or elliptical incisions under local anesthesia A traction suture is placed through the tongue well behind the growth, a V-shaped section, including the tumor, is excised by a sharp electric cautery or the electrosurgical knife; and the wound is closed with fine silver wire.

OPERATIONS ON THE TONGUE FOR CARCINOMA

The rational treatment of carcinoma of the tongue depends on a number of factors: (1) the duration, extent, and location of the lesion. (2) the presence or ab-

sence of lymph node metastases; and (3) the grade of malignancy of the tumor. The age and general condition of the patient also play a part. Most malignancies of the tongue are squamous cell carcinomas, and a biopsy should be made prior to definitive surgery.

Only extremely early lesions should be treated by local excision of the growth. Early carcinoma of the dorsum of the tongue near the tip may be removed by a wedge-shaped excision of the anterior portion of that organ. Moderately early lesions of the lateral border of the tongue not involving the floor of the mouth may be treated by dissection of the regional lymphatic nodes and partial glossectomy. Moderate involvement of the mid portion of the dorsum of the tongue may be dealt with by dissection of the regional nodes plus subtotal intraoral glossectomy. Cancer of the base of the tongue, that portion derived from the pharynx, may be treated by wide excision or by radiation. Carcinoma of any portion of the tongue with involvement of the structures in the floor of the mouth should be treated either by one of the radical operations or by intensive irradiation.

When a malignant growth of the tongue is excised, a wide margin of healthy tissue should be included. Unless the lesion is extremely early and of relatively low grade, the excision should take the form of a partial or subtotal glossectomy. In partial glossectomy, the longitudinal incision should extend back at least 2.5 cm. beyond the posterior limit of the tumor. It should also be placed on the opposite side of the median raphe, encircling the circumvallate papillae on the same side so as to include them within the excised area.

In wedge-shaped excision of the anterior portion of the tongue, an incision is started on each side, well posterior to the lesion, and is carried medially and posteriorly to meet in the raphe at least 2.5 cm. back of the lesion. The anterior ends of both segments are shaped so as to avoid giving the tongue too sharp a tip, and the segments are approximated in the midline with interrupted sutures of silver wire.

If the lesion is sufficiently extensive to warrant removal of the regional lymphatics, this is carried out on the affected side before the partial glossectomy is done and should include a dissection of the sublingual, submaxillary, and all of the superior deep cervical lymphatic nodes The nodes on the opposite side are resected at a later stage. If the patient is in good general condition and blood is given during the operation, both sides of the neck may be operated upon at one stage. It is also wise to ligate the lingual artery on the same side near its origin from the external carotid, which is just lateral to the upper surface of the body of the hyoid bone. The tendons of the digastric and stylohyoid muscles are retracted forward, and the lingual artery is found beneath and just posterior to these tendons and is ligated. Following resection of the nodes, the partial glossectomy is done with the cautery or electrosurgical knife. Repair of the tongue may be carried out in one of two ways: (1) the opposite side of the tip of the tongue may be carried across and sutured to the proximal segment of the diseased side; or, preferably, (2) the incision may include the tip on the opposite side, extending back on the opposite side of the median raphe, posterior to the circumvallate papillae. The margins of the wound are approximated with interrupted sutures. Excision of the tip is recommended by Semken to prevent the formation of a long taperlike tongue.

A subtotal glossectomy may be carried out intraorally without any enlargement of the opening, but, if the excision has to extend far back on the dorsum of the

two-thirds. The chorda tympani nerves give the sense of taste to its anterior iirds, while practically all sensation including taste is supplied to its posterior by the glossopharyngeal nerves.

ιATIONS ON THE TONGUE FOR BENIGN TUMORS

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The rational treatment of carcinoma of the tongue depends on a number of fac- (1) the duration, extent, and location of the lesion. (2) the presence or ab-

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Only extremely early lesions should be treated by local excision of the growth. Early carcinoma of the dorsum of the tongue near the tip may be removed by a wedge-shaped excision of the anterior portion of that organ. Moderately early lesions of the lateral border of the tongue not involving the floor of the mouth may be treated by dissection of the regional lymphatic nodes and partial glossectomy. Moderate involvement of the mid portion of the dorsum of the tongue may be dealt with by dissection of the regional nodes plus subtotal intraoral glossectomy. Cancer of the base of the tongue, that portion derived from the pharynx, may be treated by wide excision or by radiation. Carcinoma of any portion of the tongue with involvement of the structures in the floor of the mouth should be treated either by one of the radical operations or by intensive irradiation.

When a malignant growth of the tongue is excised, a wide margin of healthy tissue should be included. Unless the lesion is extremely early and of relatively low grade, the excision should take the form of a partial or subtotal glossectomy. In partial glossectomy, the longitudinal incision should extend back at least 2.5 cm. beyond the posterior limit of the tumor. It should also be placed on the opposite side of the median raphe, encircling the circumvallate papillae on the same side so as to include them within the excised area.

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In operations on the tongue a general anesthetic administered through an endotracheal tube with the pharynx packed off to prevent entrance of blood is of great aid. Pentothal Sodium intravenously is of especial value in oral surgery. This may be supplemented by an inhalation anesthetic or oxygen through the endotracheal tube. If a cautery is going to be used during the operation, a noninflammable anesthetic must be used.

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tongue, it is best to gain adequate exposure by an incision through one cheek extending from the corner of the mouth to the anterior border of the masseter muscle.

This operation will usually be done for moderately advanced disease and, therefore, requires excision of the lymphatic-bearing tissue of both sides of the neck in one or two stages. At the first operation, the submental, submaxillary, and entire deep cervical chain of nodes, except possibly the supraclavicular group, should be excised and the lingual artery on that side ligated. If the neck dissections are done in two stages, it is probably wise in cases requiring extensive resection of the tongue to follow the dissection of one side of the neck by making a small incision over the body of the hyoid bone on the opposite side and ligating the lingual artery at that point. If this is done, there will be little bleeding when the tongue is excised. This should not be done, however, unless most of the tongue is to be removed, as it may cause necrosis of some of the remaining tissue. If the incision extends back as far as the foramen cecum, there will be no danger of necrosis, for the base of the tongue receives considerable blood supply from the pharyngeal vessels.

In subtotal glossectomy a traction suture is passed through the anterior portion of the tongue, which is pulled well forward and upward, and the mucous membrane is divided at the junction of the ventral surface of the tongue with the floor of the mouth, from the last molar tooth on one side around the last molar tooth on the other side. The tissues of the floor of the mouth are separated from the tongue by gauze dissection. A transverse incision is made across the entire tongue posterior to the circumvallate papillae, and bleeding is carefully controlled. The dorsal mucous membrane of the tongue is sutured to the structures in the floor of the mouth. Before the tongue is excised, a deep suture is passed through its base, from the ventral to the dorsal surface near the epiglottis. This suture may be used to keep the tongue forward and also to aid in controlling hemorrhage. It is left in place and, after the operation, is brought out at the corner of the mouth as a safety measure, so that in case of secondary hemorrhage the tongue may be lifted forward and the bleeding vessel ligated. It maintains an open airway, for if the stump should fall back over the glottis, suffocation would result. After the tongue has been excised, an attempt should be made to cover the floor of the mouth by suturing the mucous membrane. The block dissection of the glands on the opposite side of the neck should be carried out as soon as the condition of the patient permits.

In a moderately extensive lesion of the tongue, not sufficiently advanced to warrant the most radical type of procedure, it is probably wise to implant radium emanation seeds in the floor of the mouth after operation.

Complete glossectomy is rarely justifiable now, for in early cancer of the tongue less mutilating operations will suffice, while in advanced cancer irradiation will usually give as good or better results with less disfigurement and a much lower mortality rate. However, if total glossectomy seems indicated, it is better to use the electrosurgical knife or an electric cautery rather than an ordinary scalpel, as they diminish bleeding and improve the chance of cure. The type of anesthetic must be chosen accordingly. It should be given through a nasal tube passed into the trachea with petrolatum gauze packed about the pharynx to prevent blood from entering the trachea, as described previously in this chapter

Of the various types of radical excision of the tongue, the method should be chosen which lends itself best to block dissection, to include the tongue, the adja-

cent tissues in the floor of the mouth, and the regional lymphatic-bearing tissue of the neck. The approach should be made from below, so that the blood supply to the tongue may be partially controlled by ligating the lingual or external carotid arteries. The operation described by Blair seems to meet these indications better than most others. His incision begins behind the angle of the jaw, curves downward to just below the inferior border of the hyoid bone in the midline, and then upward to a point just behind the angle of the jaw on the other side (Fig. 295).

Fig 295—*Line of incision in operation of Blair for excision of tongue in advanced cancer. If a tracheotomy is done, this should be carried out several days prior to operation.*

It is carried through the platysma muscle, and the upper flap, consisting of skin and platysma, is dissected up to the lower border of the jaw. The facial vessels at the lower border of the jaw are doubly clamped and divided, and the vein is again doubly clamped and divided at the level of the skin incision. The submaxillary gland is drawn upward and the facial artery is doubly clamped and divided just as it enters the gland, as far as possible from its origin (Fig. 296). The artery is tied, and the branches within about 1 25 cm. of its end are also tied. Blair thinks this is important in order to prevent secondary hemorrhage. The submaxillary gland with its surrounding tissue is dissected out. Behind the upper and outer part of the digastric tendon the fibers of the hyoglossus muscle are separated bluntly and the lingual artery is exposed and tied. After both submaxillary glands with the surrounding tissues have been removed, the muscles beneath the symphysis are divided and the periosteum and mucous membrane are stripped from the inner surface of the jaw. (Fig 297)

The cancer is thoroughly cauterized and the tongue is drawn through the opening beneath the symphysis of the jaw to expose the larynx The tongue is severed with the electric cautery or electrosurgical knife at the hyoid bone. The lower portion of each parotid gland is also removed with the cautery. The lower border of the posterior belly of each digastric muscle is sutured to the sternocleidomastoid muscle with fine catgut. The stumps of the facial arteries are left uncovered. By leaving a long stump and tying the branches, there is rarely secondary bleeding from these vessels.

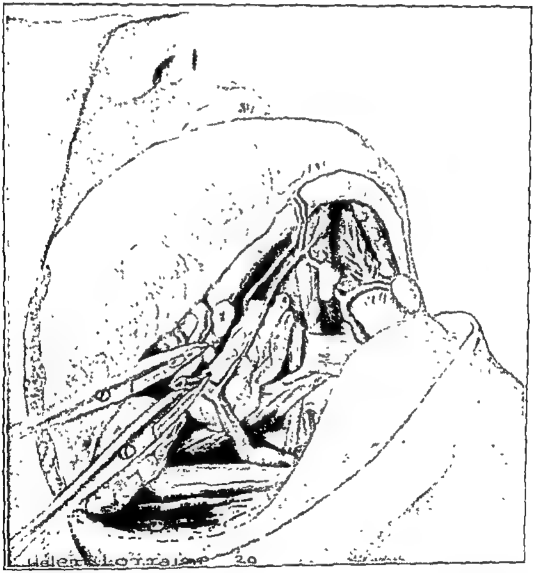

Fig. 296.—The dissection of the neck is begun and the facial vessels are doubly clamped and divided.

For feeding, a catheter is passed through one nostril into the esophagus and fastened to the upper lip by adhesive tape. This is done prior to closing the wound, as the larynx tends to fall back after the operation, making it more difficult to pass the catheter into the esophagus. The wound is closed with silk with the exception of a defect about 3 cm. in length either centrally placed or on one side of the neck through which a large soft rubber tube is passed This is sutured so that the proximal end is just within the opening and the outer end protrudes through the first layer of dressing. This permits passive or suction drainage of the mouth secretions.

Recently Blair has omitted the preliminary tracheotomy advocated by Kocher in these extensive procedures. He now finds it safer to depend on gravity suction drainage through the defect in the otherwise sutured neck wound. In cases requiring removal of both geniohyoid muscles the hyoid bone should be held forward in its normal position by a silver wire passed around the body of the bone and through a drill hole in the symphysis of the mandible. Blair states that scarring of the floor of the mouth will stiffen the tissues sufficiently to permit ultimate removal of the wire.

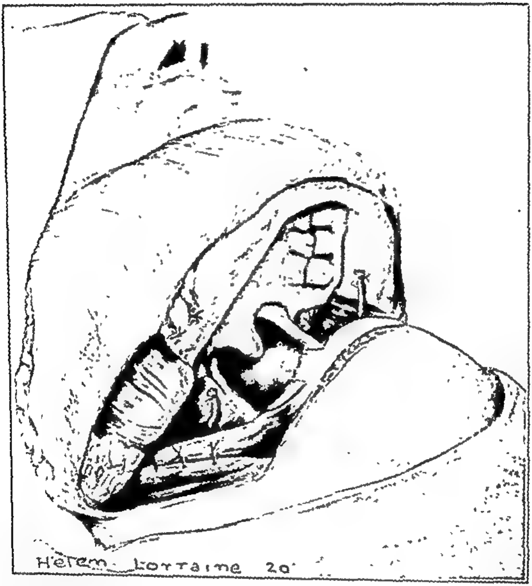

Fig. 297.—Operation of Blair completed, except suturing the wound. Note that the facial arteries are left projecting into the wound.

Immediately following this and other extensive intraoral operations the patient should be placed in the prone position with the face turned to one side, and the foot of the bed should be elevated. Any bleeding can be readily recognized. After consciousness has returned and the blood pressure has become stable, the patient should be kept in a semisitting position much of the time. Feeding is carried out by nasal tube. Large doses of antibiotics should be given.

Bilateral dissection of the deep cervical lymphatic nodes is carried out after complete healing has occurred.

Operations as destructive as total glossectomy should give a greater chance of cure than less radical procedures in order to be considered justifiable. Since even the most radical operations for carcinoma of the tongue apparently give no higher percentage of cures than irradiation of the primary lesion combined with radical resection of the cervical lymphatic-bearing tissue, this latter method of treatment seems indicated in all moderately advanced or late cases.

TREATMENT OF CARCINOMA OF THE FLOOR OF THE MOUTH

Carcinoma of the floor of the mouth may be primary, or it may be secondary to carcinoma of the tongue. The treatment of the secondary lesion has already been discussed. Early cancer of the lateral portion of the floor of the mouth should be treated with wide excision of the lesion, laterally, medially, and inferiorly by the electrosurgical knife or electric cautery. If the tumor is small, the entire lesion plus a wide margin should serve as a biopsy. The submental, submaxillary, parotid, and deep cervical chain of lymph nodes, excluding those in the supraclavicular area, should be removed on the side of the lesion, either immediately preceding or subsequent to the operation on the floor of the mouth. If there is definite involvement of the submaxillary nodes or the deep cervical chain, a complete lateral dissection of the neck should be done on the involved side and an excision of the upper cervical nodes carried out on the opposite side. If the lesion is located anteriorly, the nodes on both sides of the neck are apt to be involved, so the suprahyoid nodes and both deep cervical chains should be removed. As a rule, it is not necessary to include the supraclavicular area unless the superior deep cervical nodes are involved.

If the lesion is advanced sufficiently to involve the deeper tissues of the floor of the mouth or the jaw, it is probably best to destroy the growth by the actual cautery or by intensive interstitial irradiation. Here the nodes of both sides of the neck should be removed. If the jaw is extensively involved, it may be necessary to resect the mandible with the tissues of the floor of the mouth en bloc. However, in any case so far-advanced as to require such a procedure, irradiation alone is usually the local treatment of choice.

CARCINOMA OF THE LIP

There has been considerable difference of opinion about the relative merits of radiation as compared to surgical excision of carcinoma of the lip. The question of routine prophylactic resection of glands in the neck in cases of carcinoma of the lip is also unsettled While in recent years there has been strong evidence that carcinomas of the tongue and floor of the mouth probably can be treated best by radiation, there has also been an increasing trend toward surgical excision of operable cancers of the lip Surgical removal of metastatic glands of the neck when movable and not of a higher grade of malignancy than Grade 3 has been generally favored with radiation reserved for adherent glands and those showing Grade 4 tumor.

There has been a greater difference of opinion regarding the wisdom of excising the regional lymphatic-bearing tissue in the absence of evidence of involvement. McClure and Lam, in 1947, stated that it was unnecessary to carry out neck node dissections in patients with small, early carcinomas of the lip in the absence of palpable evidence of node involvement. Such patients should be examined each month

Fig. 298. *Fig. 299.*

Fig. 298.—G. E. L., aged seventy years, had *epidermoid carcinoma*, Grade 2, involving entire lower lip. Tumor appeared six years prior to photograph and had been kept under partial control by x-ray therapy elsewhere. In October, 1938, the tumor was excised with a wide V-shaped area which included the entire lower lip and a portion of the right cheek. Patient was directed to return in two months for dissection of neck.

Fig. 299.—G. E. L., aged seventy-two years, failed to return until mass in neck was found *fourteen months after operation*. A bilateral block dissection was done on Jan. 17, 1940. Patient had no further trouble from carcinoma of lip or neck.

Fig. 300.—G. E. L., aged eighty years, returned in 1948 because of unrelated epithelioma of left ear. The lip and neck *showed* no evidence of tumor sixteen years after first appearance and ten years after excision of lip.

for the first year and every two months during the second year. A neck dissection should be carried out immediately if a metastatic node appears. (Fig. 298, 299, and 300)

Whitcomb states that one in every four cancers of the lip has metastasized to the glands of the neck, but he, too, feels that treatment to the neck should be deferred in the absence of palpable nodes. Whitcomb recommends block dissection if the metastatic nodes are movable, but states that combined x-ray therapy and radon implants may be used.

Brown and McDowell, on the other hand, advocate neck dissections in patients with carcinoma of the lip and mouth, despite the absence of clinical evidence of lymph node involvement. While a possible exception may be justified in early low-grade lip cancers, they feel that poor general health and extreme age plus ready availability for examination are the chief justifications for deferring operation on the glands of the neck. Blair also recommends routine neck dissections because of the uncertainty of return of some patients for checkup examination and the morale-destroying factor in others of having to report for this purpose.

Judd and Beahrs reviewed 802 cases of carcinoma of the lower lip treated at the Mayo Clinic. They recommended prophylactic suprahyoid dissection on Grade 2 and 3 lesions and omitted it in early Grade 1 and late Grade 4 cancers.

Despite this conflicting opinion a policy must be formulated Surgical excision of the primary tumor of the lip is recommended, for tissue is obtained for microscopic examination, and healing is usually prompt and satisfactory. Involved, yet operable, regional nodes are removed by radical excision while fixed glands are irradiated. If the primary lesion is small and of low grade, the patient is kept under observation but the neck operation is deferred. If the lesion is more advanced or of a higher grade of malignancy, a prophylactic neck dissection is carried out. Radical excision should always be carried out if there is reasonable doubt about involvement of the glands.

Carcinoma of the lip involves the mucocutaneous border of the lower lip in more than 95 per cent of cases, occurring usually between the midline and the angle of the mouth, but occasionally so near the midline that both sides are involved early in the disease.

If the mucous membrane of the lower lip is considered as being divided into three equal segments, it is found that the lateral third drains regularly through lymphatics on the same side into the submaxillary and possibly the submental lymphatic glands, the middle third frequently shows cross drainage; and the mucocutaneous junction may drain to both sides from any part of the lip. If carcinoma involves the mucocutaneous junction or the middle third of the lip, the nodes on both sides may be involved, and dissection of the lymphatic-bearing tissue, therefore, should be bilateral. The lymphatics from the lower lip drain also to the nodes around the lower pole of the parotid gland and this area should be included in the so-called suprahyoid dissection in operations for carcinoma of the lip.

The lymphatics of the upper lip drain regularly into the submaxillary nodes, and drainage from each side of the lip is relatively unilateral. If, however, the lesion extends beyond the midline, there may be drainage to the submaxillary nodes of both sides.

OPERATIONS FOR CARCINOMA OF THE LOWER LIP

The extent of an operation for carcinoma of the lip will depend on a number of factors, the duration, location, and extent of the lesion; the grade of malignancy; and the general condition of the patient.

Theoretically, in most cases of carcinoma of the lip it would be wise to remove that portion of the lip containing the tumor in continuity with the suprahyoid nodes, as there is always the possibility of an extension of malignant cells along the lymphatic channels in areas not included in the ordinary V-shaped incision, since this incision, even when combined with resection of the suprahyoid nodes, leaves a considerable area containing lymphatic vessels between the resected lip and the tissue removed from the neck.

The Stewart type of operation is ideal so far as cancer surgery is concerned, as all of the potentially involved lymphatic tissue is removed en bloc with the primary tumor, for, according to Handley's theory of lymphatic permeation, the lymphatic vessels are as apt to contain cancer cells as the lymphatic nodes. However, metastasis from carcinoma of the lip to the submental and submaxillary nodes apparently occurs more frequently by lymphatic embolism than by gradual permeation along the lymphatic channels. It would seem, therefore, that in early carcinoma of the lip, with a lesion not more than about 1 cm. in diameter, without palpable enlargement of either the submental or submaxillary nodes, a wide excision of the lesion by a modified V incision with or without dissection of the submental or submaxillary nodes would be justifiable. The ordinary V incision has the obvious objection that in order to remove an appreciable amount of skin and subcutaneous tissue below the lip, it is necessary to remove the greater portion of the lip; but the V incision may be modified so as to give approximately the same cosmetic result and yet permit removal in one segment of a portion of the lip as well as a large segment of skin, subcutaneous tissue, and fascia over the chin. The lines of incision should be started at least 1 cm. from the margin of the tumor, carried perpendicularly downward almost to the lower border of the mandible, and then brought in at an obtuse angle to meet at the point of the chin (Fig. 301). In this way most of the lymphatic channels from the lesion to the glands will be removed. This incision has advantage over the Stewart incision in early or moderately advanced cases in that the incision through the lip and into the mouth does not communicate with the neck dissection, so the chance of gross infection of this area is avoided and yet a considerable part of the lymphatic channels between the lesion and the submental and submaxillary areas are removed. Resection of the lymphatic nodes should be carried out first, and, when the skin flap is dissected up over the submental area, a small incision can be made on the skin surface at its highest point of reflection and the incision for removal of the lip then is carried down almost to this level. Thus, the danger of contamination of the neck wound is eliminated. While this refinement of technic is perhaps less significant with present-day antibiotics, it is still desirable to avoid all likelihood of infection. At least one-half of the lip can be removed in this way, and, by dissection of the flaps back for a short distance on each side of the line of incision through the lip and tissues of the chin, closure can be obtained without too great tension on the suture line and with a satisfactory cosmetic result.

The Stewart operation is indicated in all advanced cancers of the lip which offer any hope of cure by radical surgery. As originally described, it includes an in-

cision just beneath the lower border of the mandible from the angle of the jaw on one side to the angle of the jaw on the opposite side. The incision is carried through skin, subcutaneous tissue, and platysma, and the flap is elevated to a point slightly below the level of the hyoid bone in order to expose the anterior border of both sternocleidomastoid muscles below the mastoid processes. Block removal of all lymphatic-bearing tissues in the suprahyoid area is then carried out, and the skin

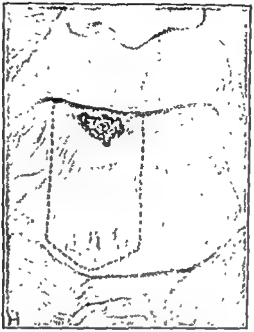

Fig. 301.—Modified V-shaped excision of carcinoma of the lower lip With adequate mobilization, this incision can be closed in a straight line with relatively little deformity.

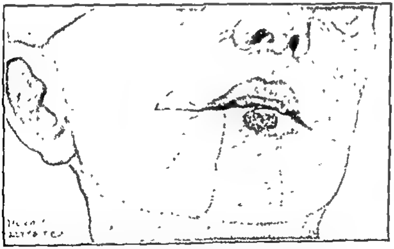

Fig 302—Incision for resection and plastic repair of the lower lip and suprahyoid dissection of the cervical lymphatic nodes. (Stewart)

flap is turned up and covered with a sterile towel. Incisions in the lip are made downward and slightly outward on each side of the cancer to connect with the original incision, including in the quadrilateral area not only the tumor but a good margin of lip on each side of it (Fig. 302) An incision is then made along the gingivobuccal sulcus on each side back to approximately the anterior border of the masseter muscle, and the skin flaps are dissected from the mandible. All the tissues over

this portion of the mandible except the skin are removed en bloc with the quadrilateral area containing the lesion. All the lymphatic channels from the lip to the submaxillary areas, which run quite near the mucous membrane in this region, are thus removed. After this entire block of tissue has been excised, the mucosa in the gingivobuccal sulcus is pulled forward, traction being made high on the two lateral flaps so as to bring forward that portion of the mucous membrane attached to the cheek and permit closure of the two flaps of skin and mucous membrane in the midline. After the mucous membrane has been completely closed, the skin is approximated with interrupted sutures of silk. Small Penrose drains are inserted in each parotid region.

If enough of the lower lip has been removed to cause puckering of the upper lip, the defect can be corrected by excising a triangular area of tissue on either side of the mouth, the base of the triangle being in line with the upper border of the lower lip. The incisions of this triangle are carried to, but not through, the mucosa. The skin and subcutaneous tissue are removed. The apex of the remaining triangle of mucosa is excised and about 1 cm. of the mucous membrane can be turned over anteriorly to form the new mucosa for the additional segment of lower lip.

The only modification of this operation recommended for most cases, in addition to the separation of the two operative fields by a narrow bridge of tissue as noted above, is that the original upper cervical flap should include only the skin and a very small amount of subcutanous tissue, and that the major portion of the subcutaneous tissue and all of the platysma in this area should be excised with the underlying lymphatic-bearing tissue.

The extent of lymphatic removal in such cases will depend upon the extent and type of the lesion and the degree of lymphatic involvement. If there is definite clinical involvement of the nodes in the submental, submaxillary, or parotid region on one side, not only these nodes but also the deep chain of nodes down to and including those around the omohyoid muscle at the point at which it crosses the internal jugular vein should be excised. If the nodes in both sides of the neck are involved, it would seem wise to carry out the extensive dissection on the most involved side, along with the submental area at the time of excision of the lip, and at the second stage to remove the nodes on the opposite side. If there is any involvement of the deep chain on either side, a complete block dissection of the neck should be done on that side, and excision of the superior deep group of nodes on the opposite side, as a rule, should be done as a second stage.

OPERATIONS UPON THE UPPER LIP

Carcinoma of the lateral third of the upper lip may be excised by an inverted V and, if necessary, a corresponding area may be removed from the lower lip. Carcinoma of the median porton of the lip may be excised by an incision described by Tanner, which is started well above and to the outer side of the ala of the nose on each side, curved outward and downward, then downward and inward, and continued down perpendicular to the lip margin, the area excised including the growth and at least 1 cm. of normal tissue on each side. Another incision is started at the upper end of the original incision, is carried down medially to the ala of the nose and then across just beneath the septum to the opposite side where it meets

a corresponding incision for that side. In this way the complete block beneath the nose, including the growth and at least 1 cm. of healthy tissue on each side, is excised. (Fig. 303.)

Daland performs essentially the same type of operation for the upper lip as he does for the lower lip. He removes the primary lesion by excising a rectangular area of lip with a margin of healthy tissue of at least 1 cm on all sides. A somewhat smaller area is removed from the mucous membrane than from the skin, and the remaining mucous membrane is separated from the muscle and skin for a distance of about 5 cm. out on the cheeks. In the upper lip the superior, and in the lower lip the inferior, line of skin incision is extended laterally on both sides for approximately 2.5 cm. Curved scissors are inserted and fibers from the adjacent muscles are divided about 1 cm. from the commissure. The mucous membrane is approximated with interrupted sutures of chromic catgut, the knots projecting into the oral cavity. The muscles are approximated with fine catgut and the skin is closed with fine silk.

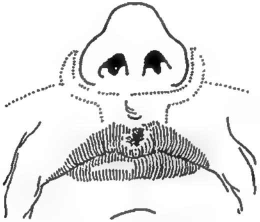

Fig 303.—Tanner's incision for resection of the mid portion of the upper lip for carcinoma.

CARCINOMA OF THE CHEEK

Early carcinoma of the buccal surface of the cheek may be excised from the inside of the mouth, but the lesion should be given a wide margin and all of the tissues in the involved area removed except the skin and a thin layer of subcutaneous tissue. Immediately preceding this operation, the regional nodes, including the submental, submaxillary, parotid, and superior deep cervical group on the affected side as well as the small group of nodes lying on the outer surface of the buccinator muscle, should be excised if there is any evidence of matastasis. In definite involvement of these nodes, a complete lateral dissection should be done on the affected side, and the nodes on the opposite side should be removed at a subsequent operation.

If the carcinoma is more advanced, the operation should be done from the outside and the lesion excised with a wide margin en bloc with the lymphatic-bearing tissue of that side of the neck, and the nodes of the opposite side should be resected later A pedicle graft may be raised to cover the defect. The primary lesion may be treated by irradiation, and, if the nodes are fixed, irradiation alone should be used.

FACIAL CARCINOMA

Carcinomas arising on the face require a wide local excision with block dissection of the appropriate cervical glands. Cosmetic considerations must be subordi-

nated to the primary need of extirpating the tumor. Macdonald states that the internal jugular vein and sternomastoid muscle should be resected routinely in all cervical dissections secondary to facial neoplasms. While this procedure will not be necessary in early tumors, it should be done in advanced carcinomas. Sliding flaps from the adjacent face or scalp may cover the defect, but pedicle grafts are frequently required.

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CHAPTER 25

OPERATIONS ON THE NECK*

GENERAL AND ANATOMIC CONSIDERATIONS; DISSECTIONS OF THE NECK

HARRY J. WARTHEN, JR.

GENERAL CONSIDERATIONS

Operations on the neck should not be undertaken unless the surgeon has a thorough knowledge of the anatomy of this region. A surgeon unfamiliar with the important structures in the neck can hardly hope to muddle through a serious operation in this region without meeting disaster The chief dangers are from ignorance of anatomy and inability to meet emergencies promptly.

There are certain general principles applicable to operations on the neck, the axilla, and the groin, which should always be borne in mind. In extensive operations in these areas the first essential is a satisfactory and thorough exposure of the parts involved. If the operator fears cutting a large vessel or an important nerve and attempts to avoid these structures by a limited exposure, he will either blindly injure them or do an incomplete procedure. These hazards may be eliminated by first exposing and identifying the important vessels and nerves and then dissecting away from them.

The patient should be kept well under the anesthetic, for light anesthesia causes congestion which will lead to unnecessary loss of blood and also make the operation more difficult. Intravenous Pentothal Sodium is of value in operations on the neck, for the absence of bulky equipment about the head of the patient facilitates the procedure. The maintenance of a clear airway is essential, however, and a nasotracheal or orotracheal tube should be inserted for supplementary nitrous oxide and/or oxygen administration.

The skin incision is undermined to secure the bleeding vessels at a distance from the margin of the wound. Every bleeding point is clamped and, when possible, vessels are doubly clamped before being divided. Dissections about the large veins of the neck may lead to air embolism if one of them should be accidentally opened. The closer the opening is situated to the base of the neck, the greater the hazard of embolism. If the hissing sound characteristic of the aspiration of air is heard, the opening must be closed promptly by a wet sponge or the finger, the wound flooded with salt solution, and the vein compressed on the central side of

*Some operations on the neck are described elsewhere under such subjects as surgery of blood vessels, nerves, the larynx, etc

the wound. If the injury to the vein is inaccessible, the wound is packed with moist gauze, which is left in position for four or five days and then gradually removed while the wound is kept flooded with salt solution. In an infected area even small veins become infiltrated and stiff and when cut may not collapse promptly. Under such circumstances air embolism is a constant hazard and the surgeon must always be on the alert for this complication.

In dissections of the neck it is always safer to cut between clamps when dividing any strand of tissue that may contain a vessel. Structures being removed should not be severed under tension unless they have been previously relaxed and the veins draining the area have been given an opportunity to fill in order to facilitate their identification. Dissection around the large vessels should be done so far as possible with a sharp knife, as tissue is traumatized with a dull blade and it is impossible to tell how much force to apply. The late J. B. Murphy, when doing a dissection of the neck, would first expose the lower part of the internal jugular vein and compress it with gauze so that it could be easily recognized during the operation.

In operations at the base of the neck the relationship of adjacent lung and pleura and, on the left side, the thoracic duct, must be borne in mind.

ANATOMY OF THE CERVICAL LYMPHATICS

The cervical lymphatic nodes surround the neck in the form of a collar at the base of the skull and the lower border of the mandible and extend down on either side as superficial and deep chains. The horizontal chain or collar is composed of five groups of nodes. Four of these, the suboccipital, the posterior auricular, the parotid, and the submaxillary, are arranged in pairs, and the fifth group, the submental, lies between the anterior bellies of the digastric muscles. The suboccipital nodes lie at the lateral border of the trapezius muscle and drain the posterior scalp region The posterior auricular nodes are located over the insertion of the sternocleidomastoid muscle and receive afferent lymphatic vessels from the posterior surface of the ear, from the posterior portion of the external auditory canal, and from the temporal portion of the scalp. The parotid nodes lie in close relation to the lower pole of the parotid salivary gland, and occasionally one or more nodes may be imbedded in the gland substance. They receive afferent lymphatic vessels from the skin of the face, eyelids, and cheeks. The subparotid glands drain the nasopharynx. All of the above nodes drain into the upper nodes of the deep cervical chain The submaxillary lymphatic nodes are three in number; the posterior one is called the chief node. They lie within the anterior part of the submaxillary triangle of the neck in close relation to the submaxillary salivary gland, and are covered superficially by the skin, subcutaneous tissue, platysma, superficial cervical fascia, and the lower border of the mandible This group receives afferent lymphatic vessels from the submental lymphatic nodes, from the lips, anterior region of the face, tongue, floor of the mouth, jaws, and cheeks; and sends efferent vessels into the deep cervical chain The submental nodes, three in number, lie in the so-called submental triangle formed by the two anterior bellies of the digastric muscles above and laterally and the upper border of the hyoid bone below. One node lies on either side of this triangle and the apex node is in intimate contact with the undersurface of the symphysis of the mandible. They receive afferent vessels from the

lower lip, the floor of the mouth, and occasionally from the anterior portion of the tongue, and send efferent vessels to the submaxillary nodes and to the deep cervical chains.

The superficial lateral cervical nodes extend from the parotid group down along the external jugular vein and lie superficial to the posterior border of the sternocleidomastoid muscle. The deep lateral cervical chains usually are described as

Fig. 304.—Arrangement of cervical lymphatic nodes and direction of lymphatic drainage in the neck

being divided into the superior deep cervical nodes, lying above the omohyoid muscles, and the inferior deep cervical nodes, lying below these muscles. It would seem more logical, however, to group the anterior portion of the inferior deep chain with the superior deep chain, as they actually form a continuous group and receive afferent vessels from a considerable portion of the scalp, the skin of the face, the

lips, the oral cavity, and the hypopharynx. The areas around the face and mouth in which malignant epithelial tumors are most apt to develop drain into the deep cervical lymphatic chains. Tumors arising in or about the auricle metastasize to the local periauricular nodes, then spread around or within the cervical tail of the parotid gland and thence to the adjacent submandibular lymph nodes. Lesions anterior to the auricle are more likely to spread into the anterolateral triangle, whereas those arising posterior to the auricle metastasize also into the posterior cervical triangle. The supraclavicular nodes, on the other hand, receive afferent vessels from the posterior scapular regions, the arms, and the axillae, and only a few communicating vessels connect this group of nodes with the remaining portion of the deep cervical chains. (Fig. 304.)

The lateral neck region is divided into the sternocleidomastoid, or carotid area, and the posterior triangle. The carotid area is covered superficially by the sternocleidomastoid muscle and extends downward and forward in the form of a rectangle from the mastoid process above and behind to the anterior portion of the clavicle and sternum below and in front. Among the most important structures that pass through this region are the carotid artery, the internal jugular vein, and the vagus nerve. Most of the deep cervical lymphatic nodes lie in this area in close association with the sheath of the internal jugular vein. The posterior cervical triangle is bounded in front by the posterior border of the sternocleidomastoid muscle, posteriorly by the anterior border of the trapezius muscle, and below by the clavicle. It is covered superficially by the skin, subcutaneous tissue, platysma, and superficial fascia; and the deep cervical fascia forms the floor. The efferent vessels from both the deep cervical lymphatic chains and the supraclavicular nodes enter the right and left thoracic ducts and the great vessels directly. There is no direct connection between the cervical lymphatics and the mediastinal lymphatics.

The conditions for which surgery of the cervical lymphatic system is indicated are: first and most important, metastases from malignant epithelial tumors of the lips, oral cavity, hypopharynx, pharynx, larynx, nasal accessory sinuses, skin of the face, and primary epithelial tumors in the neck, as for example, branchiogenic carcinomas; second, malignant tumors primary in the lymphatic nodes, as endotheliomas, lymphosarcomas, and Hodgkin's disease; third, inflammatory conditions of these nodes, including tuberculosis; and fourth, injuries to the larger lymphatic ducts, especially the left thoracic duct.

Surgical excision of the lymphatic-bearing tissue for metastatic malignancy should be carried out always in the form of a block dissection; that is, the dissection should start at the periphery and the suspected area should be removed in one mass, which, when possible, should include the primary growth. The cervical field may be divided into four areas for purposes of dissection: the suprahyoid, the upper neck, the lower neck or supraclavicular, and the entire cervical field which extends from the base of the skull and lower border of the mandible above to the clavicle below, and from the midline anteriorly to the trapezius muscle posteriorly. Dissection of the suprahyoid area, which usually should be bilateral, is indicated in lesions of the lips and occasionally in lesions of the cheeks and mucous membrane covering the upper jaws, if there is no evidence of gross involvement of the nodes. If there is evidence of moderate involvement of the nodes in the suprahyoid area, the entire

upper portion of the deep cervical chains should be excised, and if there is pronounced enlargement of the nodes in the suprahyoid area or involvement of the upper nodes of the deep cervical chain, the complete neck dissection should be done. In other words, if cures are to be obtained by surgery in carcinomas of the face and oral cavity, the tissues excised, particularly the lymphatic structures, must extend well beyond any obvious involvement.

SUPRAHYOID BLOCK DISSECTION OF THE NECK

Suprahyoid block dissection of the neck is indicated most often for carcinoma of the lips but is indicated occasionally for carcinoma of the upper jaw and cheek. In any case it is desirable from the standpoint of cancer surgery to connect the excision of the primary lesion with the excision of the lymphatics and when possible to remove all of the intervening lymphatic-bearing tissue. Carcinoma of the upper lip occurs infrequently, so dissection is rarely indicated for this condition. Most suprahyoid dissections, therefore, are for carcinoma of the lower lip.

Theoretically, in order to remove all of the lymphatic tissue, it would be desirable to remove en bloc the involved portion of the lower lip with all of the lymphatic channels connecting the lower lip with the suprahyoid lymphatic nodes This should be done in all cases of advanced or even moderately advanced carcinoma of the lower lip. The objection to this procedure is the fact that despite antibiotics and technical safeguards it is impossible to carry out such a procedure without subjecting the tissues of the neck to the hazards of gross infection from the mouth. Because of this danger, the excision of the lip usually is done as a separate procedure from the dissection of the neck.

The patient is placed on his back with shoulders slightly elevated by a small pillow. The lower portion of the face, the entire anterior and lateral aspects of the neck, and the upper portion of the chest are painted with an appropriate antiseptic, followed by alcohol. The upper drapes are fastened to the skin over the mandible by closely spaced interrupted silk sutures. It is important that this be done because during the operation it is necessary to turn the patient's head from side to side, and, unless the drapes are attached firmly, they are apt to be displaced, with resulting contamination of the operative field.

Two types of incision are used. An incision may be started just below the parotid gland on one side and carried just beneath the lower border of the mandible to a corresponding point on the opposite side. The lower flap is dissected down to the level of the hyoid bone and should include only the skin and a very small amount of subcutaneous tissue. The skin above this incision is dissected up to about the mid portion of the border of the mandible on each side to expose the fascia over the lower portion of the masseter muscles. This type of incision is preferable when the lip is to be removed en bloc with the lymphatic structures, or, in other words, when the Stewart type of operation is to be performed. If the lip is not to be removed en bloc with the lymphatic tissue, a more satisfactory incision is one that starts over the mastoid process on one side, curves downward in a cervical crease to the upper border of the hyoid bone, and then up to the mastoid process on the opposite side. (Fig. 305.) The entire skin flap is dissected up well above the lower border of the mandible, only the skin and a very small amount of subcutaneous tissue being included.

The head is now turned sharply to the side which shows the greater involvement, and the side showing less involvement is dissected first. The original incision is deepened through the platysma and superficial cervical fascia, and the anterior border of the upper portion of the sternocleidomastoid muscle is exposed. The facial vessels are exposed as they pass upward over the lower border of the mandible a short distance in front of the angle of the jaw, where they are freed, doubly clamped, centrally divided, and individually ligated. The fascia over the lower portion of the masseter muscle and lower border of the mandible is dissected down to the inferior border of the mandible. The superficial cervical fascia is incised at the lower border of the mandible and the tissues are pushed downward to expose the contents of the submaxillary triangle. The incision through the cervical fascia along the lower border of the mandible is then carried back to the anterior border of the sternocleidomastoid muscle to expose the lower pole of the parotid gland.

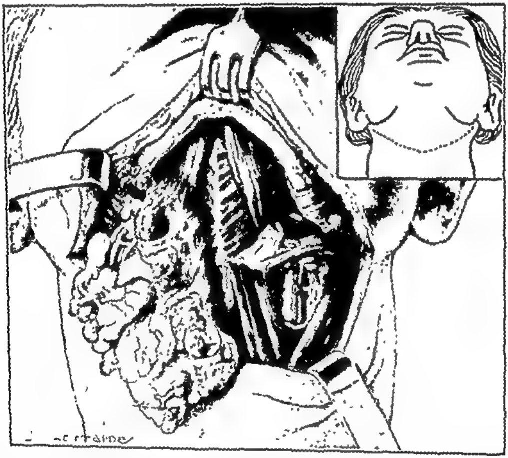

Fig 305 —Dissection of the suprahyoid lymphatic-bearing tissues and the carotid group of deep cervical nodes, as carried out for carcinoma of the lower lip.

The tissues between the lower pole of the parotid gland and the submaxillary gland are carefully dissected downward, chiefly by blunt dissection, and the lower pole of the parotid gland is excised, care being taken to doubly clamp before dividing the external jugular vein as it passes down through the lower pole of the parotid. A branch of the facial vein is exposed in the same area, doubly clamped, divided, and ligated.

This portion of the dissection is abandoned temporarily, and dissection is begun below over the posterior belly of the digastric muscle. The tissues are dissected

up over the posterior belly of this muscle; the facial artery is exposed as it emerges from beneath this muscle, is doubly clamped, divided, and the proximal end carefully ligated. Division of this artery frees the tissues in the lower part of the submaxillary triangle so that the remainder of the dissection is accomplished easily. The mass of tissue now is dissected from behind forward and from below upward until the submaxillary salivary gland is separated from its bed. This gland is retracted downward and forward and the branch of the lingual artery to the gland is divided and ligated The submaxillary structures are carefully separated upward from the hyoglossus muscle. The numerous small vessels in this portion of the field are clamped. When the dissection reaches the lateral border of the mylohyoid muscle, the posterior border of the muscle is freed and retracted forward. The mass of tissue is drawn downward and backward to expose the submaxillary duct, which is separated from the surrounding tissues, doubly clamped, divided, and the distal end is ligated. The dissection is carried across the anterior belly of the digastric muscle and this portion of the operation is temporarily abandoned after checking the incision for complete hemostasis.

The head is now turned sharply to the opposite side and the same procedure is carried out until the dissection reaches the anterior border of the anterior belly of the digastric muscle The head is then turned back to the mid-position and by upward retraction the tissue is dissected away from the floor of the submental space, which consists of the median raphe and the anterior portion of the mylohyoid muscles. It is important to carry the dissection up to the lower border of the symphysis of the mandible, so that the apical node will be removed. This latter maneuver, described by Fischel, simplifies the dissection of the submental triangle.

All bleeding is carefully controlled. The incision is flushed out with warm normal saline solution The skin flap is replaced, the skin margins are approximated with interrupted on-end mattress sutures of fine silk, and a small rolled rubber tissue drain is inserted through each angle of the wound at the level of the lower pole of the parotid gland. A gauze dressing is applied directly over the wound, and mechanic's waste is applied over each submaxillary fossa to obliterate the dead space. Special care should be used in applying the dressing to avoid pressure necrosis of the skin flaps.

COMPLETE UNILATERAL BLOCK DISSECTION OF THE NECK

Complete unilateral block dissection of the neck is carried out usually for metastatic carcinoma from the tongue, floor of the mouth, or lower jaw. It may be indicated also in metastatic carcinoma from the lips when there is gross involvement of the submental, submaxillary, or superior deep cervical nodes It may be carried out in separate stages as a bilateral procedure or in combination with a less radical procedure on the opposite side.

The patient is placed on his back with the shoulders elevated on a small pillow and the head is turned sharply to the nonoperative side After a sterile cleanup the drapes are attached above the upper border of the mandible by interrupted silk sutures. The remaining margins may be fixed by clips A skin incision described by Semken (Fig. 306) gives excellent exposure. The primary incision begins over the upper end of the sternocleidomastoid muscle immediately below the tip of the

mastoid process and is carried downward and forward about midway between the anterior and posterior borders of this muscle until the lower anterior end of the muscle is approached, where the incision goes backward in a broad curve along the clavicle to the anterior border of the trapezius muscle. A second incision is carried forward from the primary incision of the midline of the neck at the level of the body of the hyoid bone and, as far as possible, in one of the transverse cervical creases. The anterior end of the second incision is carried upward as it approaches the midline of the neck to the lower border of the symphysis of the mandible. These incisions should pass through only the skin and subcutaneous tissue.

The dissection of the posterior skin flap is carried backward until the anterior border of the trapezius muscle is exposed. This flap may include the skin, subcutaneous tissue, and platysma muscle, but care should be exercised in raising the inner surface of the platysma muscle so as to leave this surface absolutely clean. If there is enlargement of the supraclavicular nodes, it is best to leave the lower portion of the platysma attached to the deeper tissues. The flap is protected with warm saline pads.

Fig 306.—Incision for complete unilateral dissection of the lymphatic-bearing tissue of the neck. (Semken)

The incision over the sternocleidomastoid muscle is deepened through the thin fascial covering of the muscle, and the posterior border of this structure is exposed and separated from the underlying structures. It is important to avoid injury to the spinal accessory nerve as it emerges from the upper part of the posterior border of the muscle. The sternocleidomastoid muscle is retracted forward and the sheath of the internal jugular vein is exposed This is incised upward to the level at which the joint trunk of the ranine and facial veins enters the internal jugular vein, which occurs at about the level of the hyoid bone. The tendon of the omohyoid muscle is divided as it crosses the vein. In exposing the lower portion of the vein it may be necessary to divide the clavicular portion of the sternocleidomastoid muscle. The sheath of the vein is carefully dissected back until the junction of

the sheath with the bed of the vein is reached, where the sheath is again incised longitudinally throughout the extent of the previous incision. (Fig 307.) Here care must be taken to avoid injury to the vagus nerve as it lies in the sheath with the great vessels between the artery and the vein. By deepening the incision along the bed of the vein, the scalenus anticus muscle is exposed and the phrenic nerve is found coursing downward and forward on it.

Fig 307.—Dissection of the lymphatic nodes of the neck with preservation of the sternocleidomastoid muscle and internal jugular vein. The lateral portion of the sheath of the jugular vein has been removed

This portion of the dissection is discontinued temporarily and the incision over the clavicle is now deepened through the anterior division of the cervical fascia from the jugular vein back to the anterior border of the trapezius muscle. The external jugular vein is doubly clamped, divided, and the lower end is ligated. The clavicular portion of the omohyoid muscle is divided. The subclavian vein is carefully exposed, and an incision made in the sheath of this vein is carried forward to join the incision in the jugular sheath at the junction of these two vessels. In the left jugulosubclavian angle is the thoracic duct, which curves upward and forward from within the thorax to enter the subclavian vein near its junction with the internal jugular. Injury to this duct must be avoided. After the duct has been isolated, several large cervical lymphatic vessels will be found entering it or one of the nearby veins. These large lymphatic vessels should be doubly clamped, divided, and ligated. If the dissection is on the right, the right lymphatic duct should be treated in a similar manner. The sheath of the subclavian vein is now dissected

back to the point where it joins the bed of the vein and is incised throughout the extent of the field. All of the loose lymphatic-bearing tissue is dissected from before backward and upward to expose the scalenus anticus muscle, the phrenic nerve, the brachial plexus, which must be protected, the scalenus medius and posticus, and the levator scapulae muscles. When the anterior border of the trapezius muscle is reached, the dissection is discontinued and the mass of loose tissue is divided by a posterior incision carried upward to about the same level as the incision in the sheath of the jugular vein. The previously protected spinal accessory nerve is preserved if there is no evidence of gross metastasis in the lymphatic structures around it. The wound is flushed out thoroughly with warm normal saline solution, the mass of tissue is wrapped in a saline sheet, the lower skin flap is replaced in position and covered with warm saline sheets, and the dissection in this area is discontinued.

The triangular flap situated in the lower neck anteriorly is then dissected free to the midline. The anterior portion of the fascia covering the sternocleidomastoid muscle is dissected forward, and the muscle is separated from the underlying structures up to the level of the transverse incision and is retracted backward. The anterior portion of the sheath of the jugular vein is freed as far as the descending hypoglossal nerve, which lies at the junction of this portion of the sheath with the bed of the vein. The sheath is removed carefully above the level of the junction of the ranine and facial trunk with the jugular vein because a thick pad of loose tissue containing numerous lymphatic vessels covers the vein above this point. The anterior sheath of the vein is incised along the line of the descending hypoglossal nerve, and the dissection is then carried upward and forward to include the fascia over the ribbon muscles of the neck extending to the midline and upward to the hyoid bone. (Fig. 308.) Care should be taken to leave the fatty pad covering the lateral surface of the larynx, as it protects the superior laryngeal nerve. This part of the wound is flushed out with warm normal saline solution and covered with warm saline sheets.

The upper quadrilateral skin flap is dissected to a point above the lower border of the mandible from the midline anteriorly to the mastoid process posteriorly. This flap should consist only of the skin and a very small amount of subcutaneous fat, the platysma being left in place to be removed with the underlying structures. The head is turned back to the mid-position. The skin on the opposite side of the midline is dissected up to expose the fascia over the anterior belly of that digastric muscle. This fascia may be divided either by the cautery or electrosurgical knife, and the area between the anterior bellies of the two digastric muscles (the submental space) is dissected toward the exposed side, care being taken to remove all of the loose tissue including the apical node which lies immediately beneath the symphysis of the mandible. The dissection is carried over the proximal anterior digastric belly and temporarily discontinued.

The head is again turned to the opposite side. The fascia over the lower portion of the mandible is incised, the facial vessels are exposed as they cross the lower border of the mandible about 2.5 cm anterior to the angle of the jaw, separated, doubly clamped, divided, and individually ligated. The incision in the fascia is carried back to the mid portion of the sternocleidomastoid muscle just below the

mastoid process. The upper anterior portion of the sheath is dissected from this muscle, and the inner surface of the muscle is carefully separated from the lower pole of the parotid gland and retracted posteriorly.

The upper transverse incision is deepened to expose completely the lower pole of the parotid gland, which is divided transversely, and the lower segment is retracted downward. In dividing the parotid the anterior facial and the external jugular veins should be identified and clamped before they are cut. The cervical fascia is divided just below the lower border of the mandible and pushed downward, to expose the contents of the submaxillary space, which are now dissected out from before backward and from below upward.

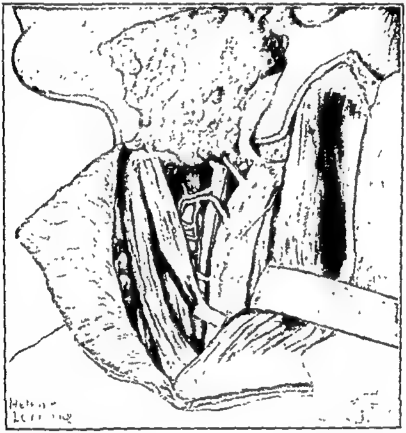

Fig 308 —All lymphatic-bearing tissue and the sheath of the jugular vein have been removed to the level of the entrance of the combined ranine-facial vein into the jugular vein.

The submaxillary branch of the facial nerve has to be sacrificed during this dissection, but since the procedure is carried out usually on both sides, the resulting deformity is balanced and hence not especially noticeable The submaxillary gland is drawn downward and backward and the lateral border of the mylohyoid muscle is retracted forward. The submaxillary duct, which is frequently in close relationship with the lingual nerve, is thus exposed, freed, doubly ligated, and divided The dissection is then carried from below upward over the posterior belly of the digastric muscle, the facial artery is exposed just above the upper border of this muscle, doubly clamped, divided, and ligated All of the loose tissue in the submaxillary space, including the submaxillary salivary gland, is dissected backward, care being taken not to injure the lingual and hypoglossal nerves in the submaxillary space. The carotid artery, which is situated posterior to and below the pos-

terior belly of the digastric muscle, is carefully avoided. (Fig. 309.) The internal jugular vein is exposed anteriorly and the incision in the sheath of the vein along the descending hypoglossal nerve is carried upward to the upper limits of the field. The entire mass is retracted backward, the dissection is carried back over the jugular vein, and the entire lateral portion of the sheath is dissected from the upper portion of the vein. The upper portion of the sheath is divided posteriorly at its junction with the bed of the vein. The posterior belly of the digastric muscle is now freed and retracted upward along with the remaining portion of the parotid gland, and the jugular fossa is thus exposed. The thin fascia over the upper portion of the vein is divided and dissected downward and posteriorly. (Fig. 310.)

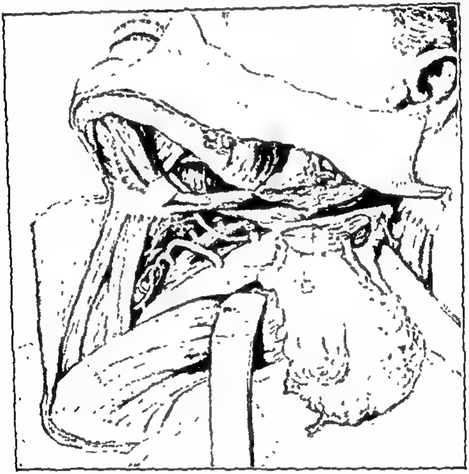

Fig. 309.—After removal of the suprahyoid lymphatic-bearing tissue, including the submaxillary salivary gland and the lower pole of the parotid gland.

In this part of the dissection the proximal segment of the spinal accessory nerve is exposed. If there is no obvious involvement of the tissues adjacent to this nerve, an attempt should be made to save it by stripping the tissues down along the nerve to a point near its entrance into the sternocleidomastoid muscle, *where if necessary* the nerve may be divided and separated from the tissues, to be sutured later. If, however, there is any evidence of involvement of the adjacent tissues, the nerve should be sacrificed. The entire mass of tissue is now passed beneath the sternocleidomastoid muscle, and the upper and lower operative fields are joined. All of the lymphatic-bearing tissues in the lateral and anterior portion of the neck are thus removed in one mass.

If this dissection is carried out carefully as described, the only important lymphatic vessels which are divided are those crossing the lower portion of the jugular sheath near the thoracic duct. Special care must be taken in the final part of the dissection to avoid injury to the internal carotid artery and the vagus nerve.

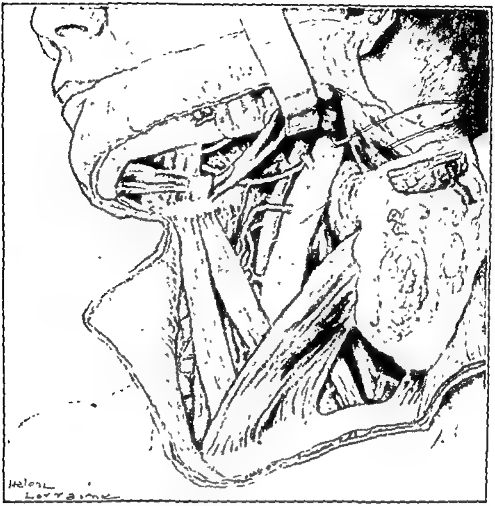

Fig 310 —Dissection completed except for the area posterior to the upper portion of the internal jugular vein Note that the entire anterior, lateral, and medial portions of the sheath of the jugular vein have been removed. The entire area of lymphatic-bearing tissue is removed in one mass.

The wound is flushed out with warm normal saline solution, a stab wound is placed in the posterior-inferior angle of the dissected space, and a rolled rubber tissue drain is inserted through this angle. A similar drain is placed in the upper posterior angle of the wound close to the cut surface of the lower pole of the parotid gland. The skin edges are carefully approximated by on-end mattress sutures of fine silk and a snug dry gauze dressing is applied. Mechanic's waste is placed outside the sterile dressings in the submaxillary and supraclavicular fossae, to help obliterate the dead space. It is extremely important that too much pressure be avoided, for necrosis of the skin flaps may result

In the operation described above the internal jugular vein and the sternocleidomastoid muscle are preserved, although by so doing the technical difficulties of the operation are considerably increased This procedure would seem desirable,

however, if the lymphatic nodes are only moderately enlarged and are not adherent to the sheath of the vein or to the muscle. If there is any attachment to these structures, they should be removed en bloc with the lymphatic-bearing tissue (Fig. 311).

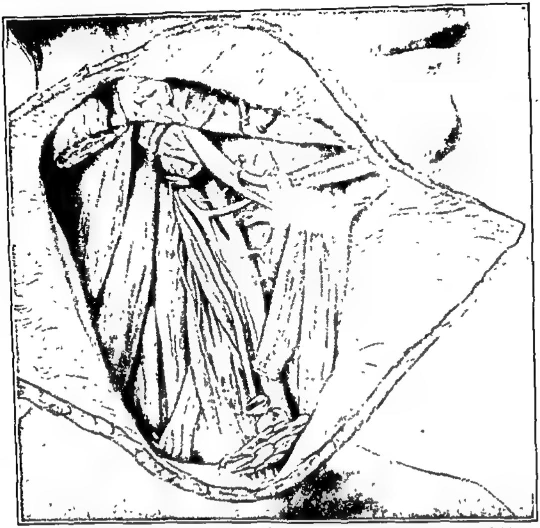

Fig. 311.—Completed block dissection of one side of the neck. The sternocleidomastoid muscle and internal jugular vein have been removed. Transfixing sutures should be placed distal to the ligatures on the internal jugular vein.

If these structures are to be removed, the skin flaps are formed as previously described, the lower end of the sternocleidomastoid muscle is divided, and the lower end of the jugular vein is exposed, doubly clamped, divided, and doubly ligated. The dissection is then carried upward, the sheath of the vein is divided on either side, and the anterior and lateral portions are taken with the vein to the point at which the common facial vein enters the internal jugular, where the dissection is temporarily discontinued. The upper end of the sternocleidomastoid muscle is cut across, the lower pole of the parotid gland is divided and pushed downward, and the submental and submaxillary areas are dissected from before backward, as previously described. The anterior tissues are dissected back and the anterior sheath of the vein is divided above the level of the entrance of the ranine and facial trunk. The vein is freed from its bed, doubly ligated, and divided above. The sheath of the vein is incised posteriorly and the dissection is carried backward and downward, as previously described. It is important to place the ligatures on the jugular vein

at a considerable distance from the end of the stump so that they will not be blown off. The use of a transfixing suture distal to the ligature on both proximal and distal stumps gives added safety to the ties. Closure of the wound and drainage are carried out as previously described.

In this dissection special care must be exercised to avoid injury to the lingual, hypoglossal, and vagus nerves, and to the internal carotid artery.

If a bilateral dissection is to be carried out, it is wise either to separate the two operations by a period of several weeks or to preserve the internal jugular vein on the less involved side.

BLOCK DISSECTION OF THE UPPER CERVICAL LYMPHATIC-BEARING TISSUE

Block dissection of the upper cervical nodes includes the removal of the sublingual, submaxillary, and parotid groups of nodes as well as the entire superior deep cervical chain. It is usually done for carcinoma of the lips and oral cavity and occasionally for squamous cell carcinoma of the face. It may be bilateral or associated with block dissection of the other side.

The patient is placed on his back with the head turned sharply to the non-operative side. The drapes are fastened in place as previously described. The incision described by Semken gives the best exposure and is almost identical with the upper portion of the incision for complete block dissection of the neck (Fig. 306), the only difference being that in this operation the posterior incision is made about 2 cm. posterior to the anterior border of the sternocleidomastoid muscle. It is carried downward from the tip of the mastoid process along the anterior portion of the muscle to about the level of the lower border of the cricoid cartilage. The second incision extends from the midline at the level of the hyoid bone laterally to join the first incision and should, when possible, follow a cervical crease. The third incision extends from the lower border of the symphysis of the mandible to join the second incision in the midline over the body of the hyoid bone. The upper quadrilateral skin flap is dissected up well above the lower border of the mandible, and the fascia is exposed over the lower portion of the masseter muscle. Only the skin and a very small amount of subcutaneous tissue should be included in this flap. The transverse incision is then deepened through the platysma, and the anterior-inferior triangular flap of skin, subcutaneous tissue, and platysma is freed to the lower end of the incision and as far forward as the midline of the neck The skin along the posterior margin of the original incision is dissected back to expose the external jugular vein. The skin on the opposite side of the midline is raised so as to expose the fascia over the anterior portion of the anterior belly of the digastric muscle of that side. The fascia is freed from the anterior border of the sternocleidomastoid muscle throughout the extent of the incision, and the muscle is freed from the underlying fascia and separated with care from the fascia overlying the outer surface of the lower pole of the parotid gland. The internal jugular vein is exposed by retracting the sternocleidomastoid muscle outward and backward An incision is made along the posterolateral surface of the vein from the lower portion of the wound upward to the level of the entrance of the ranine and facial trunk into the internal jugular, at which level the thin fascial sheath of the vein merges

into a thick layer of fatty tissue containing numerous lymphatics. The sheath of the vein below the ranine-facial trunk is dissected forward over the lateral surface of the vein to the descending hypoglossal nerve, where the sheath is again incised longitudinally to the same extent as the posterior incision. The loose tissue and fascia are dissected forward and upward over the omohyoid, sternohyoid, and sternothyroid muscles to the level of the hyoid bone, care being taken to protect the fatty pad over the lateral surface of the larynx which covers the superior laryngeal nerve. The remaining portion of the dissection is now carried out as described for the complete unilateral operation except that the dissection of the posterior triangle is limited. When it reaches the level of the lower end of the original incision, the entire mass is freed by an incision along the posterior and inferior margins of the field. Especial care must be taken in this part of the operation to avoid injury to the internal carotid artery and vagus nerve.

A stab wound is made into the posterior-inferior portion of the dissected space and a small rolled rubber tissue drain is inserted. Another small drain may be placed through the upper portion of the posterior incision in the region of the lower pole of the parotid gland. Throughout the operation the skin flaps must be protected by warm normal saline sheets and the wound should be flushed out thoroughly with warm saline solution at the completion of each stage of the operation. The skin edges are approximated with on-end mattress sutures of fine silk. A light dry gauze is applied and a mechanic's waste dressing is placed lightly over the submaxillary fossa.

DISSECTION OF THE SUPRACLAVICULAR SPACE AND POSTERIOR TRIANGLE OF THE NECK

This operation may be carried out as the second stage of the complete lateral dissection of the neck or as the second stage of the radical operation for carcinoma of the breast when it is found that the nodes in the apex of the axilla are involved or when the nodes above the clavicle are palpable and there is no other contraindication to the radical operation.

If the operation is done as the second stage of the complete lateral dissection of the neck, the original posterior incision is carried downward along the mid portion of the sternocleidomastoid muscle and curved backward along the upper border of the clavicle to the anterior margin of the trapezius muscle. If it is the second stage of the operation for carcinoma of the breast, the same type of curved incision may be used, so that the perpendicular portion of the incision is carried down about 1.5 cm. in front of the posterior border of the sternocleidomastoid muscle; or an inverted T-shaped incision may be used, which has the advantage of giving shorter skin flaps with a better blood supply and therefore less danger of necrosis. In either event, the dissection is made as outlined for this portion of the complete block dissection of the neck. If the operation is the second stage of a cervical dissection, the dissection must be made up to the level at which the upper stage ended, and the mass is then removed by an incision along the anterior border of the trapezius muscle. If the operation is carried out as the second stage of the breast operation, the dissection must be carried well back into the supraclavicular area and up to the level of the cricoid cartilage.

After the dissection is completed, a small rolled rubber tissue drain is inserted through a stab wound into the posterior part of the field, and the skin edges are approximated with on-end mattress sutures of fine silk. Sterile dry gauze and mechanic's waste dressings are applied, as previously described.

WOUNDS OF THE THORACIC DUCT

During operations around the junction of the jugular and subclavian veins on the left side, special care should be taken to avoid injury to the thoracic duct, which arches upward and forward to enter the left innominate vein at this point. If the duct is injured, an attempt should be made to repair it with interrupted sutures of arterial silk. If repair is impossible, the duct should be ligated and a snug pressure dressing applied. If the right lymphatic duct is divided, both ends should be ligated.

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CHAPTER 26

OPERATIONS ON THE NECK (CONTINUED)

PRIMARY TUMORS; CONGENITAL CYSTS AND FISTULAS; TUBERCULOSIS OF CERVICAL LYMPH NODES

HARRY J. WARTHEN, JR.

TUMORS OF THE CAROTID BODY

Fortunately, tumors of the carotid body occur infrequently, but when they are encountered they are best treated surgically. These tumors may be benign or malignant. When they are benign, the operation, performed early, is not especially difficult. Many of these patients are seen late, when the tumor has reached a large size, which greatly increases the difficulty of removal. If the tumor is malignant, the walls of the carotid arteries are frequently invaded, and ligation and excision of segments of the vessels may become necessary during the course of the operation. Postoperative disabilities may be as high as 83 per cent (MacComb).

The type of incision should depend to a large extent on the size of the tumor and the degree of fixation to the surrounding structures. If the tumor is of moderate size and does not appear to be especially fixed, a transverse incision should be made in one of the cervical creases. If it is large and fixed, it may be necessary to approach it through a long incision over the anterior border of the sternocleidomastoid muscle. The first incision is preferable. The muscle is freed and retracted posteriorly and the posterior belly of the digastric muscle is mobilized and retracted upward. Both the internal jugular vein and the common carotid artery are dissected free below the tumor, and strips of tape or loops of heavy catgut are passed around them so that the lumen of either vessel can be compressed if severe hemorrhage occurs during the liberation of the tumor. It is also desirable, when possible, to expose the internal and external carotids and the jugular vein above the tumor and to place loops of catgut around them. In this way the danger of severe hemorrhage is eliminated, but the dissection must be done with care, to avoid injury to the common or internal carotid arteries and the vagus and hypoglossal nerves. If it is found that the tumor cannot be removed without danger of injury to either the common or the internal carotid, a biopsy should be made. If the tumor is benign, an incomplete removal is justified in most cases. If, on the other hand, the tumor is malignant, and especially when there appears to be danger of injury to the vessels, a snug but not completely occlusive fascial ligature should be applied to the common carotid below the tumor and the wound should be closed. If no cerebral symptoms result, the tumor may be excised after several weeks. Ligation of the carotids following several weeks of partial occlusion is less dangerous than if

done as a primary procedure. If it is decided to proceed with the removal of the tumor at the first operation, the lower pole, the upper pole, and then the anterior border of the tumor should be freed to give the best possible exposure when the separation of the tumor from the vessels is attempted. An extracapsular excision is desirable, but unfortunately this cannot always be done, especially in the larger tumors. After the tumor has been removed, the fascia and platysma are approximated with interrupted sutures of fine silk. If the carotids are ligated, the foot of the bed should be elevated and oxygen administered postoperatively.

Lahey advocates that before operation in any case of suspected carotid body tumor the carotid be compressed until ten minutes of occlusion three times a day can be tolerated. If removal of the tumor entails ligation of the carotids, he carries out this procedure only in the presence of proved malignancy.

CAROTID SINUS SYNDROME

In 1947, Cattell and Welch reported three cases of this condition relieved of symptoms following denervation of the carotid sinus. Surgery should be reserved

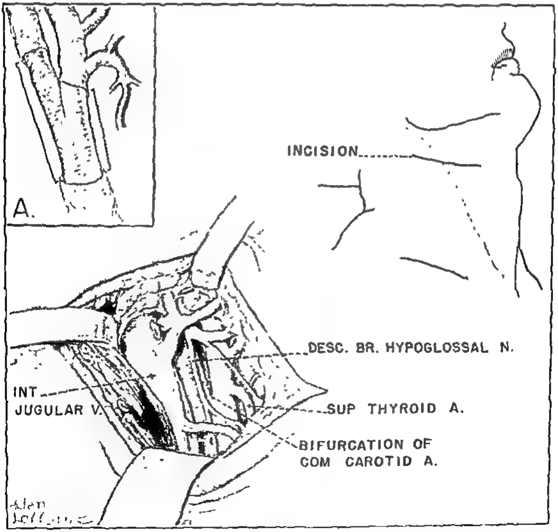

Fig 312.—Incision for denervation of the carotid sinus The exposure and relationship of the bifurcation of the common carotid artery is shown. (Modified from Cattell and Welch.)
Inset *A* indicates the extent the adventitia should be stripped from the common and internal and external carotid arteries The intercarotid tissue should also be excised.

for those patients with symptoms so severe as to prevent them from carrying out their usual occupation despite having received appropriate medical treatment and in cases presenting a mixed or cerebral type of response.

The operation consists of stripping the common, internal, and external carotid arteries at the bifurcation, sectioning the carotid sinus nerves, and removing the intercarotid tissue. Cattell and Welch recommend cyclopropane and ether anesthesia, which may be supplemented by procaine block in the hyperactive carotid sinus. An incision is made along the anterior border of the sternomastoid muscle, centered at the level of the upper border of the thyroid cartilage. (A transverse incision in a cervical crease would give good exposure.) The muscle is retracted laterally, exposing the carotid sheath which is incised carefully to avoid damage to its contents. The internal jugular vein and sternocleidomastoid muscle are retracted laterally. (Fig. 312.) The adventitia is stripped by sharp dissection from the common, internal, and external carotids, for at least 2 cm. above and below the bifurcation (Fig. 312, *A*). The procedure may be facilitated by injecting normal salt solution between the media and adventitia. The intercarotid tissue which contains the carotid body is freed laterally and inferiorly from the bifurcation and divided well above it. The incision is closed in the usual manner.

CONGENITAL CYSTS AND FISTULAS OF THE NECK

Cystic Hygroma

A cystic hygroma arises from a primitive lymph sac and, while benign, the youth of the patient and the frequent ramification of the growth make its removal difficult. These cystic tumors usually originate in the posterior triangle of the neck, most often just above the clavicle, but in their development they may extend in almost any direction, occasionally going beneath the clavicle and down under the pectoral muscles or even into the mediastinum. These cysts are almost always multiocular but may be unilocular. They arise occasionally from lymphatic rests in the upper portion of the neck. Most of these tumors develop in childhood and they are not infrequently present at birth or develop soon after. Less frequently hygromas arise in the axilla or inguinal region.

The treatment of cystic hygroma of the neck is primarily surgical, and the only satisfactory results thus far reported have followed radical surgical excision of the tumor. Since most of these tumors occur in children, a considerable number of them in infants, the attending physician often hesitates to refer them for operation when the tumor is first noticed. This delay not infrequently results disastrously, for infection may develop in the cyst, or the tumor may reach massive proportions or may invade the mediastinum, making complete excision difficult or impossible. However, aspiration may be of value preliminary to irradiation when operation is contraindicated. Open drainage of these cysts is unsatisfactory and may be hazardous due to the likelihood of infection.

Operation in the large tumors is always a long and tedious procedure, but if proper care is exercised in the control of hemorrhage and the prevention of infection, the results are gratifying

When the tumor is present at birth or develops soon thereafter, it may be desirable to delay operation for a few months to permit the patient to withstand

the procedure better, unless the growth of the tumor is too rapid. During this period of delay, the rate of growth should be noted and also the direction in which the tumor tends to spread. Every effort should be made to protect the child from respiratory infections, as many of the spontaneous infections in hygromas follow infections of the upper respiratory tract.

Excision of large cysts in infants should be carried out under light general anesthesia, preferably drop ether. Pentothal Sodium intravenously may be given to older children. In small tumors a straight incision through the skin is used, but in large tumors the excess of thin adherent skin should be excised, care being taken to leave a sufficient amount for closure without tension. The prolongations of the tumor may extend between various important structures, so the operator must have a thorough knowledge of the anatomy of the neck and upper mediastinum. If the tumor cannot be completely removed or if operation is contraindicated, irradiation either by high voltage x-ray or by radium is indicated, although there are a number of objections to strong irradiation in young children. The effects of the intensive irradiation on nearby tissues, particularly on the various growth centers in adjacent bones, cannot be controlled; and, in the neck, the thyroid, the thymus, and the parathyroid glands may be affected, with serious consequences.

Lateral Neck Cysts and Fistulas

These cysts and fistulas were formerly supposed to result from persistence of the branchial clefts. Recently discovered evidence indicated that they may develop from the thymic duct or from the lateral thyroid ducts. A cyst and fistula may occur together and a lateral neck cyst may be converted into a fistula either by incision and drainage or by rupture through the skin. These structures are located in the anterior triangles of the neck, and, in congenital fistulas, the opening is usually located just above and medial to the sternal end of the sternocleidomastoid muscle. Occasionally, however, the opening is located in the upper part of the neck, and this is especially apt to occur when a sinus results from the incision or rupture of a cyst, as cysts occur more frequently in the upper anterior neck region. In a large percentage of cases, a fistulous tract extends from the external opening in the skin upward along the course of the great vessels to an inner opening in the pharynx above.

Lateral neck cysts should be excised completely. The operation is simple, if there has been no previous infection, and may be done under local anesthesia. To render the scar less conspicuous, the incision, when possible, should be made in a cervical crease and is carried down through the skin, subcutaneous tissue, platysma, and superficial layer of cervical fascia. The anterior border of the sternocleidomastoid muscle is thus exposed, freed, and retracted posteriorly, to expose the deep layer of cervical fascia, which is incised and the cyst wall exposed. The wall of these cysts is frequently thin and may be ruptured easily, so the dissection should be done with care in order that none of the wall is left to cause a recurrence. In the upper portion of the neck, care must be taken not to injure the great vessels, especially the internal jugular vein and important nerves, such as the vagus and hypoglossal. The excision will be more difficult if there has been previous inflammation of the cyst. Under such circumstances, particularly if the cyst is large, it

may be necessary to make the skin incision along the anterior border of the sternocleidomastoid muscle to obtain a satisfactory exposure. If located high in the neck, the cyst may be densely adherent to nearly all of the structures in the upper cervical region, including the great vessels and the vagus and hypoglossal nerves, and must be separated from them by careful sharp dissection. After the cyst has been entirely removed and complete hemostasis obtained, the fascia and platysma are approximated loosely with interrupted sutures of fine catgut or very fine silk and the skin with interrupted on-end mattress sutures of fine silk.

Cutler recommends the treatment of cervical fistulas by the injection of a sclerosing solution, preferably a modification of Carnoy's solution, which is prepared as follows:

Absolute Alcohol	6 c.c.	Glacial Acetic Acid	1 c.c.
Chloroform	3 c.c.	Ferric Chloride	1 gram

Jarman has treated branchial cleft cysts by aspiration and injection of pure carbolic acid. Lendgren has used aluminum chloride and phenol for this purpose. The technics of injection may be found in the original articles.

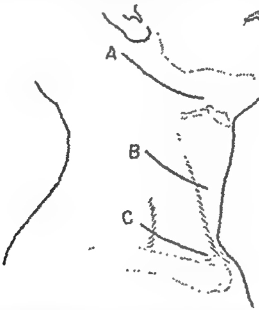

Fig. 313.—Stepladder incisions, which may consist of two or three transverse incisions to permit removal of a congenital fistula. The lower incision may be made in an elliptical manner to incorporate the external opening, while the upper incisions give access to the deeper structures.

Surgical excision of these congenital defects is preferable to the uncertainties and dangers of the injection method. Whereas excision of these so-called branchial cleft cysts is apt to be simple, excision of lateral cervical fistulas is certain to be more difficult. Before operating upon them, it is well to determine definitely if the fistulous tract is complete, and this may be done by injecting a dye, such as methylene blue, through the external opening and watching to see whether it appears at an internal opening in the pharynx. The dye stains the lining of the tract and so helps to identify it during the subsequent dissection.

Since these operations may be long and tedious, they are best done under general anesthesia. Intratracheal anesthesia is especially useful in these patients. The

patient is placed in the dorsal recumbent position, with the head of the table elevated slightly, and a small flat pad is placed beneath the shoulders. The head is extended and turned to the opposite side.

If the external opening of the fistula is located high in the neck, it may be possible to obtain a satisfactory exposure through a single transverse incision; but if the opening is in the lower portion of the neck, the "stepladder" technic of Bailey should be used. *This consists of two transverse incisions, a short lower elliptical one*

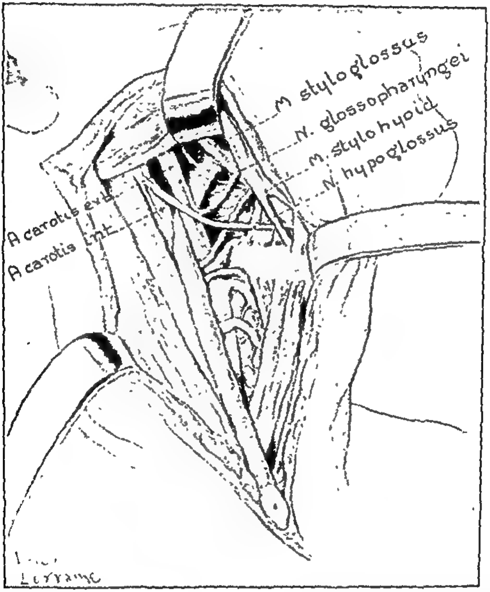

Fig 314.—A lateral neck fistula which passed between the external and internal carotid arteries. Transverse incisions in creases of the neck are preferable to the indicated diagonal incision.

to mobilize the fistulous opening and a higher incision along a crease in the neck through which the major procedure is carried out. *(Fig. 313.)* This incision extends through the skin, subcutaneous tissue, platysma, and the superficial layer of the cervical fascia. These structures are dissected up for a short distance above and below the line of incision, and the anterior border of the sternocleidomastoid muscle is exposed, freed, and retracted posteriorly. The fistulous tract is dissected out from below upward. *Injury to the great vessels must be avoided.* The hypo-

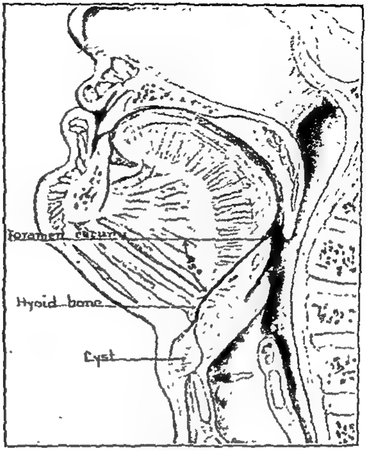

Fig. 315.—Cross section showing the relations of the cysts and fistulas of the thyroglossal tract, according to Sistrunk.

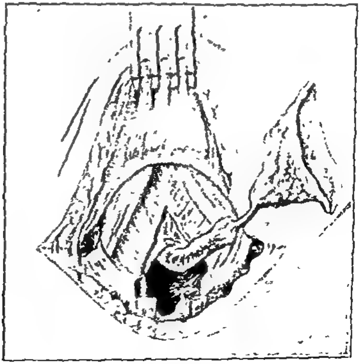

Fig. 316.—The middle segment of the hyoid bone has been removed and the thyroglossal tract is being dissected (Sistrunk.)

dissect out the tract and about 0.5 cm. of tissue on all sides of it, "coring" it out between the hyoid bone and the foramen cecum. The tract passes backward and upward at an angle of 45° from the upper surface of the center of the hyoid bone in the midline of the neck to the base of the tongue. (Fig. 315.) A transverse incision about 5 to 6 cm. in length is made at the upper level of the hyoid bone, the skin and platysma are reflected, and the cyst, which is beneath the raphe connecting the sternohyoid muscles, is freed from the surrounding tissue up to the hyoid bone through which the tract may pass. The muscles attached to the center of the hyoid bone are divided and about 0.5 to 0.8 cm. of the mid portion of the bone is resected. From this point to the foramen cecum no attempt is made to dissect out the duct, but the tissue is removed as a core. (Fig. 316.) The "coring" process is facilitated if the finger is placed in the mouth, and the base of the tongue is pressed downward and forward. In this way the fistulous tract and portions of the following structures are removed: the hyoid bone, the raphe joining the mylohyoid muscles, the geniohyoglossi muscles, and the foramen cecum. (Fig. 317.)

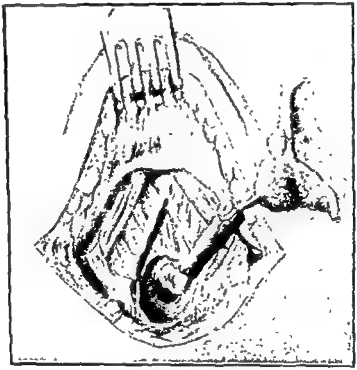

Fig. 317.—The dissection has been completed, and the foramen cecum is exposed.

The wound in the tongue is closed carefully, the geniohyoglossi are approximated, and the soft tissue over the ends of the hyoid bone is sutured together with fine chromic catgut to approximate the ends of the bone. A small rubber tissue drain may be inserted through the midportion of the incision, but it is better to omit drainage when possible. The skin is closed with on-end mattress sutures of fine silk. Antibiotics may be desirable postoperatively for several days.

LOCATIONS OF INCISIONS IN NECK

Despite the general knowledge that incisions should be placed in the natural creases of the part, this rule is violated frequently in surgery about the neck. Holman states that an incision that crosses the normal lines of the skin in a region

characterized by the constant motion of the neck will result in a thick unsightly scar which may even assume the character of a keloid. (Fig. 318.) Careful closure of the platysma muscle with fine interrupted silk or cotton sutures will permit removal of the skin sutures in forty-eight hours, with complete fading of the stitch marks.

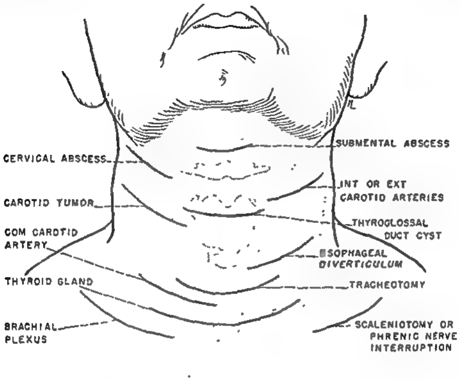

Fig 318.—Recommended placement of incisions in the neck paralleling normal lines and folds of the skin. Incisions of this type give inconspicuous scars (Modified from Holman.)

TUBERCULOSIS OF THE CERVICAL LYMPHATIC NODES

Due to the pasteurization of milk, tuberculosis of the cervical lymph nodes is now rarely seen. Extensive operations for this condition are done less frequently since it has been shown that good results can usually be obtained by nonoperative measures. Roentgen ray therapy both early and late and ultraviolet irradiation produce a favorable reaction in this type of tuberculous infection, and by their judicious use with proper hygienic measures the majority of such cases can be improved and a considerable number cured Surgical procedures, therefore, are not indicated unless conservative measures have failed. Antibiotics should be used as prophylaxis in the immediate pre- and postoperative periods. The drug may be started the day before and discontinued not later than two weeks after operation.

When individual nodes or small groups of nodes are to be excised, the incision, when possible, should be placed in one of the cervical creases to minimize the scar. It is important, however, to obtain adequate exposure so that the operator may be able to recognize important structures and thus avoid injuring them. All involved nodes must be removed Occasionally it is necessary to do a complete unilateral neck dissection, in which case the operation is carried out very much as has been described for metastatic carcinoma, only it is, of course, not so essential to avoid lymphatic paths. The wound is closed without drains and the dead space is obliterated by light pressure dressings

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CHAPTER 27

THE THYROID GLAND

HYPERTHYROIDISM; STRUMA; CARCINOMA; ADENOMATOUS GOITER; PARATHYROID ADENOMA

CARRINGTON WILLIAMS

Simple goiters, as a rule, are not difficult surgical problems and usually can be removed safely when the same precautions are taken as in the removal of other cervical tumors. In large adenomatous goiters, especially those extending far down into the mediastinum, the difficulties are greatly increased, and in some the ingenuity and skill of the surgeon may be sorely tried. It is reassuring to recall that substernal goiters, even those extending deep within the thorax, receive their blood supply from vessels originating in the neck. There are, therefore, no vascular connections in the mediastinum, the only attachments being relatively light adhesions, the result of pressure on the surrounding structures.

HYPERTHYROIDISM

Patients with hyperthyroidism, either from diffuse parenchymatous hyperplasia or from toxic adenomas, also may present difficult surgical problems, the chief difficulty being not so much the technic of operation as the general management of such cases, the decision as to the best time for operation and the type of operation to perform. The proper use of iodine as a preoperative measure in hyperthyroid patients has greatly reduced the dangers of thyroidectomy and to some extent has also reduced the technical difficulties of the operation. Unfortunately, these patients have often received iodine for a long time before they are referred for operation and have passed the optimum time for operation before the surgeon sees them. Such cases can now be prepared with thiouracil derivatives and converted into good risks. In spite of the increasing knowledge of the endocrine system as related to the thyroid gland, the hyperplastic gland must be destroyed in order to cure the patient The destruction of the function of the gland by drugs is only temporary. The destruction of the cells by radiation has in the past been unsatisfactory. The use of radioactive iodine for this purpose is too recent for definitive judgment, but it would seem that its uncertainty of action and its possible deleterious effects on other organs is sufficient to limit its use to experimental cases. The operation of removal of the major part of the thyroid gland gives excellent results and is now done with a minimum of mortality and morbidity Subtotal thyroidectomy is certainly the treatment of choice for this disease.

STRUMA

Infection is a factor in the development of the strumas which may be defined as thickening and hardness of the gland throughout its entirety. These strumas are the result of laying down of scar tissue or infiltration of lymphocytes with destruction of the acini of the gland. The metabolic rate is usually low. In the early stages antibiotics may have a favorable influence, and later roentgen therapy should be used. There are cases in which there is considerable pain and there are a few in which the trachea is compressed sufficiently to cause respiratory difficulty. The most important differential diagnosis is from cancer; the complete symmetrical and smooth contour of the gland usually is sufficient to make this differentiation. When operation seems necessary the usual technic can be followed, but on account of the structure of the gland special care must be exercised to protect the recurrent laryngeal nerves and the parathyroid glands.

CARCINOMA

The most favorable type of carcinoma of the thyroid is the low-grade papillary type which is often not suspected prior to operation. These tumors usually occur in the single adenoma, and for that reason all single adenomas should be removed as soon as they are found. When the lesion is malignant and the capsule is intact and not invaded, lobectomy on the affected side is the operation of choice. When the capsule is invaded, the lobe outside involved, or when there is extension into the glands of the neck, radical dissection of the neck including removal of the sternomastoid muscle and the internal jugular vein should be done. The digastric muscle should be the upper limit of this dissection. The technic of radical neck dissection is described in Chapter 25. This operation should always be followed by roentgen therapy, and when the extent of the disease indicates very radical treatment, tracheotomy should be done at the time of operation.

When the lesion is nonencapsulated adenocarcinoma, the diagnosis is usually made before operation, and the complete unilateral lobectomy, radical neck dissection, and tracheotomy, when indicated, are carried out according to plan.

ADENOMATOUS GOITER

All single adenomas and all adenomas with hyperthyroidism should be removed. Some surgeons advocate lobectomy for single adenoma on account of the possibility of malignancy, but this seems too radical. Removal of the adenoma with a small amount of surrounding normal gland is sufficient. The tumor should be carefully examined for evidence of malignancy, and, if cancer is suspected either by gross or microscopic appearance, the remainder of the lobe should be removed.

The gland containing multiple adenomas when small may be kept under observation The indications for operative interference are steady growth, disfiguring tumor, pressure on the trachea, or substernal extension. This condition is usually bilateral. As much normal gland as possible should be preserved and it may be necessary to leave some small tumors in order to save thyroid tissue.

ANESTHESIA IN THYROID OPERATIONS

Thyroid operations may be done under local or general anesthesia. A local anesthetic following the administration of one of the barbiturates is satisfactory in the

majority of cases, but in very nervous or hypersensitive patients light nitrous oxide and oxygen anesthesia may also be used. The local anesthetic is injected along the line of the proposed transverse incision, first intradermally and then subcutaneously. The infiltration is carried upward along the posterior borders of the sternocleidomastoid muscles to block the anterior divisions of the cervical nerves. It is wise also to inject the anesthetic solution over the region of the thyroid gland, between the cervical fascia and the prethyroid muscles. After the prethyroid muscles have been separated in the midline and both lobes of the thyroid gland exposed, a small amount of procaine solution should be injected into the upper poles and between the isthmus of the thyroid and the trachea. If this technic is carried out properly, there is rarely need for supplementary inhalation anesthesia, but if the patient complains of pain or is unduly nervous, a light general anesthetic is indicated. In some clinics epinephrine is added to the local anesthetic solution, but, since hyperthyroid patients are very sensitive to this drug, its use would seem to be unwise and unnecessary.

It is wise to discuss the question of anesthesia with the patient before operation If the patient is highly nervous and frightened at the prospect of being conscious during the procedure and reassurance is not convincing, light general anesthesia is indicated. This may be induced by Pentothal Sodium and continued with nitrous oxide-oxygen. In any case where there are signs or symptoms of tracheal compression, an intratracheal tube should be inserted, but in the absence of compression it should not be used. In cases with extreme compression the intratracheal tube should be placed with local anesthesia before the general anesthesia is started. Preliminary to any type of anesthesia, opiates and barbital should be given in doses appropriate to the individual patient and the degree of nervousness.

SUBTOTAL THYROIDECTOMY

The patient is placed in the dorsal recumbent position, the chin is directed straight forward and the head moderately extended, and special care is taken that this extension does not cause embarrassment to respiration.

The technic of partial thyroidectomy is essentially the same in all forms of goiter, but in hyperplastic thyroids the tissue is more vascular and friable and less thyroid tissue is left. The operation is done through a transverse collar incision, its length depending to some extent upon the size of the gland (Figs. 319 and 320). In a moderately enlarged thyroid the incision should be started just lateral to the anterior border of the right sternocleidomastoid muscle and carried along one of the cervical creases about two fingerbreadths above the upper border of the sternum to a similar position on the opposite side. For cosmetic reasons it is important not to place the incision too high, but it should be borne in mind that the chin is extended and that the skin in the region of the incision is displaced upward by an enlarged thyroid gland. After removal of the enlarged gland, with the chin in the normal position, the scar may descend far enough to overlie the inner ends of the clavicles, where it will tend to spread out and become more conspicuous. It is convenient to mark the line of incision with the pressure of a thread and crosshatch this line with two light scratches in order to place the line properly and to suture it accurately at the end of the operation. The skin, subcutaneous tissue, and platysma are incised to expose the anterior jugular veins beneath the platysma If the trans-

Fig. 319.—Thyroidectomy. The skin incision.

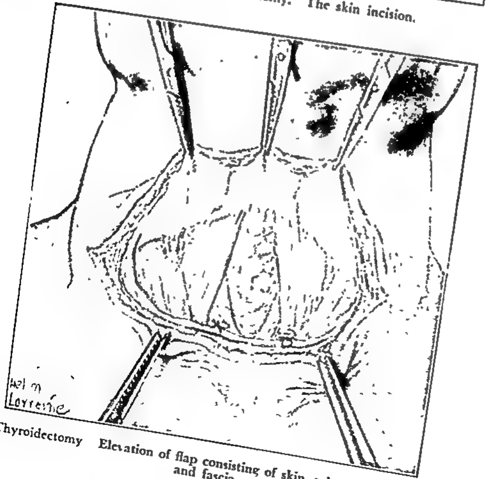

Fig 320 —Thyroidectomy Elevation of flap consisting of skin, subcutaneous tissue, platysma, and fascia

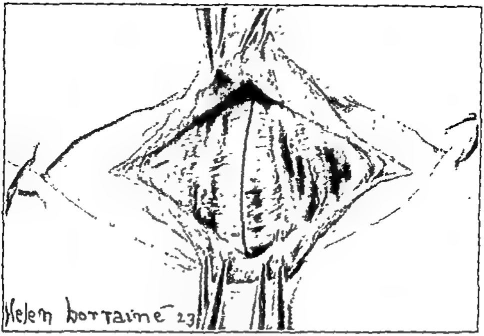

Fig. 321 —Thyroidectomy The tissues are dissected up in the midline and the ribbon muscles are separated by a longitudinal incision.

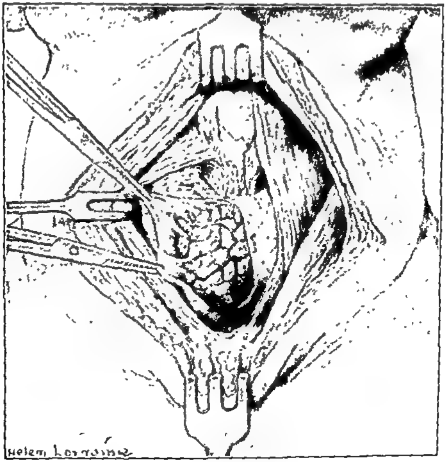

Fig 322 —Thyroidectomy Separation of deep layer of cervical fascia (false capsule) from the thyroid gland

verse incision does not include the fascia (Fig. 321), it will be unnecessary to divide these veins. If the thyroid is greatly enlarged, it may be wise to divide the prethyroid muscles transversely a short distance below the attachment of the sternothyroid to the larynx, and if this is the plan it is best to leave the fascia in place to hold the sutures when the muscles are later approximated. By dividing the muscles high, their nerve supply is preserved. With only moderately enlarged thyroids, transverse section of the prethyroid muscles is usually unnecessary, and under such circumstances the transverse incision should be carried through the fascia, down to the sternocleidomastoid and prethyroid muscles, and the skin, subcutaneous tissue, platysma, and fascia dissected up. Before the fascia is incised transversely, it is

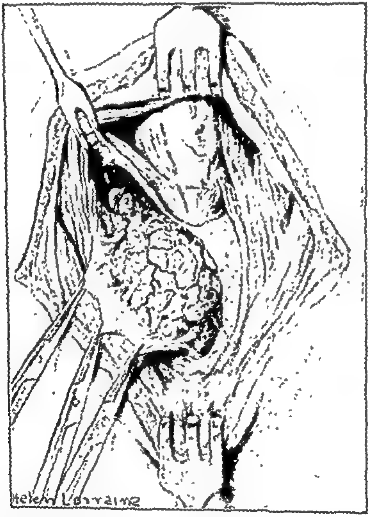

Fig 323.—Thyroidectomy. Exposure of right upper pole of thyroid gland.

best to make a small perpendicular incision over each of the large veins and doubly clamp, divide, and ligate them. By including the fascia in the flaps a better exposure can be obtained when the muscles are separated in the midline, as they may be retracted more readily when not covered by fascia. If at any time during a thyroidectomy the exposure is inadequate, the prethyroid muscles should be sectioned without hesitation, as a good exposure is the first essential to a safe thyroid operation. The flaps are dissected up as far as the upper border of the thyroid cartilage and down to the sternal notch When the goiter is adenomatous and not large, it is easier to leave the fascia in place and divide it longitudinally in the midline.

The sternohyoid muscles are separated in the midline throughout the length of the exposure and the sternothyroid muscles are separated from the sternum to the level of their insertion in the thyroid cartilage. After this, the thin fascial layer overlying the thyroid gland is incised with care so as not to injure the large vessels beneath it, and this fascial layer is separated from the anterior surface of the gland (Fig. 322) by blunt or sharp dissection. The suspensory ligament or fascia of the thyroid is then divided after clamping and ligating the contained vessels. The space between the medial surface of the right upper pole and the larynx is opened up by

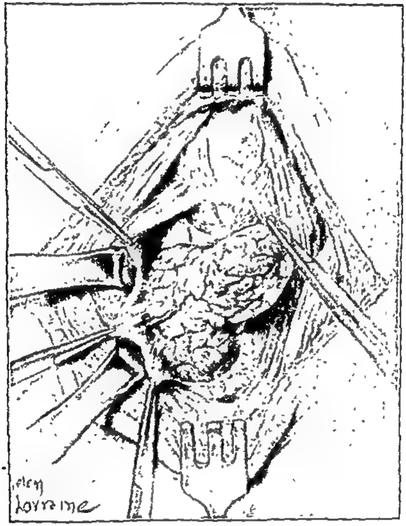

Fig. 324.—Thyroidectomy. Delivery of upper pole after ligation and division of superior thyroid vessels

blunt dissection, and the upper pole is separated from the adjacent tissues by carefully dissecting them upward with a small piece of gauze in a curved clamp. In this way the superior thyroid vessels are safely isolated (Fig. 323), they are clamped with three clamps, divided between the lower two, and the proximal segment is doubly ligated. This method avoids the danger of *retraction of the proximal vessels before they are properly ligated.* The prethyroid fascia or false capsule is now dissected to the right to the point at which the middle thyroid vein leaves the gland (Fig. 324). This vessel is doubly clamped, divided, and the lateral segment is ligated (Fig. 325). This is an important point in the operation, for, as emphasized by Hertzler, the prethyroid fascia splits here, the inner layer extending around the

gland to the trachea, while the anterior layer passes laterally to fuse with the carotid sheath. It is important, therefore, to follow the inner surface of the posterior layer around the gland to its posterolateral border. The dissection is then extended downward to expose the inferior thyroid veins, which are clamped, divided, and ligated. Traction is now made on the upper pole, which is dislocated forward and toward the midline. After the upper pole has been delivered, traction is applied to the mid portion of the gland and the entire lobe is thus rotated medially. This traction may be applied in a number of ways, but a small, sharp-toothed, rake retractor has been found most efficient for this purpose. In applying the retractor to the lateral surface of the gland, it is naturally important to avoid injury to the larger superficial thyroid veins.

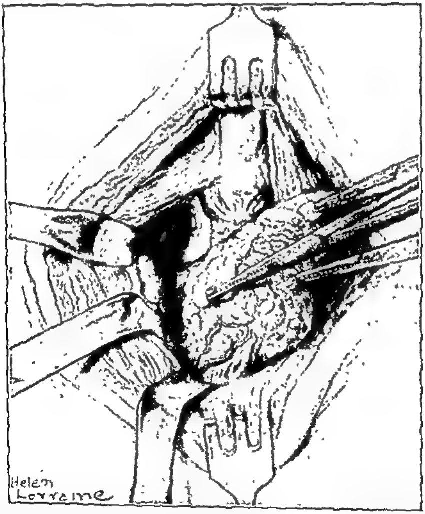

Fig. 325.—Thyroidectomy. The middle thyroid vein has been ligated and divided and the right lobe of the gland retracted *forward and to the left* to expose the branches of the inferior thyroid artery.

The decision must now be made as to how much gland will be left on the right side. As a preliminary to this decision, it is important to inspect carefully the posterolateral surface of the gland, especially that portion adjacent to the branches of the inferior thyroid artery, for parathyroid bodies. The loose connective tissue adjacent to the gland should also be examined for these bodies. If one or more parathyroids are found closely adherent to the substance of the thyroid, that portion of the gland had best be left in place. If, on the other hand, the parathyroid

bodies are found attached to the adjacent connective tissue which was separated from the thyroid during the preliminary dissection of the false capsule, it may be advisable to leave little or no thyroid tissue on the right side. If the recurrent laryngeal nerve is visible, it should be kept carefully in view during the subsequent dissection. Whether or not the nerve is exposed, it is extremely important to proceed with care during the next stage of the operation. If little or no gland is to be left on the right side, the lobe is retracted forward and to the left and the individual branches of the inferior thyroid artery are clamped and divided as they enter the gland. Small clamps should be used for this purpose and the vessels should be divided and promptly ligated with fine silk or fine cotton. If one of these vessels should escape, it is safer to expose the main stem of the inferior thyroid artery and ligate it, thus avoiding the danger of injury to the recurrent nerve. After these vessels have been ligated, the dissection is carried toward the trachea and then across this structure, removing the entire isthmus (Fig. 326).

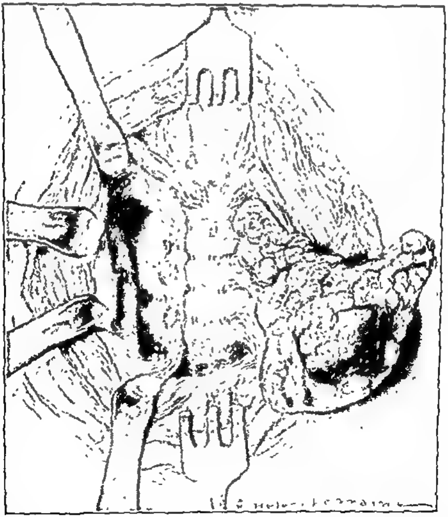

Fig 326.—Thyroidectomy. The entire right lobe and isthmus have been dissected free.

The thyroid is then separated from the trachea to well beyond the midline, and much the same procedure should be carried out on the left side, except that when all of the right lobe has been removed, it is wise to leave a moderate sized segment of the posteromedial portion of the left lobe in place. After the upper pole vessels, the middle thyroid vein, and the inferior thyroid veins have been divided and ligated,

a number of small sharp-pointed hemostats are applied to the left lateral surface of the gland and the line of incision is made immediately anterior to them. The incision is then carried a little beyond the mid portion of the lobe, and the right lobe and isthmus are turned to the left, when another incision is made in the medial surface of the gland at the junction of the anterior and left lateral surfaces of the trachea. This incision is extended laterally and slightly posteriorly to meet the lateral incision, thus removing a very considerable part of the left lobe. The proportion of gland that should be left is difficult to estimate, but in clear-cut hyperthyroidism with diffuse parenchymatous hyperplasia, probably not more than one-tenth of the entire gland should be left, as an average. The amount removed depends on a number of factors, such as the age and general condition of the patient, the degree of toxicity, and to a lesser extent upon the size of the gland. (Fig. 327.)

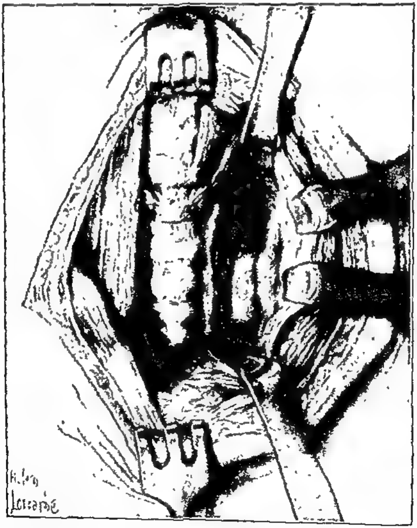

Fig 327.—Thyroidectomy. The entire thyroid gland except a small posteromedial segment of the left lobe has been removed.

This type of operation, properly carried out, leaves the anterior surface of the trachea bare but protects the laryngeal nerves, and so-called tracheitis is unusual as a postoperative complication, which probably indicates that this condition is not the result of exposure of the trachea but is very likely due to the injury of branches of the superior laryngeal nerve. Coller and Boyden state that tracheitis actually appears to occur less frequently when the isthmus is removed than when a layer of

thyroid tissue is left over the trachea. The margins of the remaining segment of the left lobe may be approximated with fine mattress sutures but this is not necessary. The wound should be gently flushed out with warm normal saline solution and both fossae carefully inspected for small bleeding points before closure.

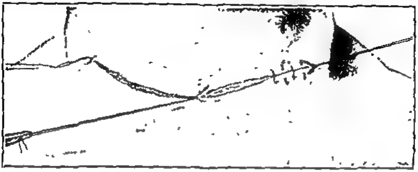

Fig. 328.—Thyroidectomy. Skin closure.

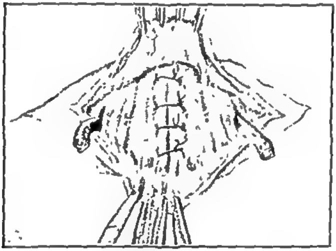

Fig 329.—The ribbon muscles are approximated by interrupted sutures Small drains may be brought out through the lateral angles of the wound.

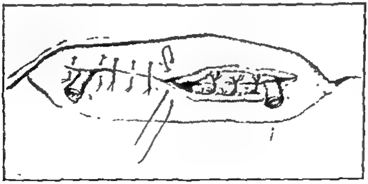

Fig. 330.—Method of closing the platysma and skin.

The question of whether to drain has occupied considerable space in literature on thyroidectomy during past years. It is usually considered inadvisable to drain if silk or cotton is used for sutures and ligatures, whereas if catgut is used it is felt that the greater production of serum in the wound makes it advisable to drain. Fine silk is preferred for sutures and ligatures, and formerly thyroidectomy wounds

were rarely drained (Fig. 328). For the past few years it has been the practice to insert one or two very small rolled rubber tissue drains in a small percentage of the cases, leaving them in place for not more than twenty-four hours. Frequently only one drain is used and this is inserted in the midline just beneath the prethyroid fascia. When two drains are used, they are placed, one in each fossa, and are brought out through stab wounds at the lateral border of the prethyroid muscles and through the lateral angles of the wound (Fig. 329). It is felt that there is less swelling when temporary drainage is established, and no ill effect from this type of drainage has been noted.

The wound is closed with interrupted sutures of fine silk or cotton for the sternothyroid and sternohyoid muscles. The platysma and fascia are carefully approximated with fine interrupted sutures, and the skin is closed with alternating on-end mattress and plain interrupted sutures. Plain interrupted sutures are first placed at each end of the incision, then while lateral traction is made on these sutures, another interrupted suture is inserted in the center of the incision if there is no drain, or if there is one, a suture is placed on each side of the drain (Fig. 330). Tension is then made on these sutures while the other sutures are placed. If the cervical fascia and platysma have been approximated properly, the skin sutures may be removed at the end of forty-eight hours, and a fine mesh gauze collodion dressing is applied over the incision. For this dressing a narrow strip of sterile gauze is used, which is dipped in freshly prepared collodion and immediately placed over the incision. If this is done properly, no other dressing is necessary.

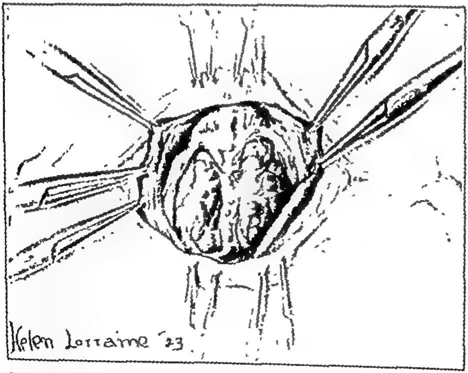

Fig. 331.—Exposure of the thyroid gland by retraction of the ribbon muscles

The above technic may be modified in the following manner, with the advantage of preserving the internal and posterior portion of each lobe, thereby giving added protection to the recurrent nerve and the parathyroid glands: The transverse incision is made down to the platysma muscle (Fig. 319), the skin and subcutaneous

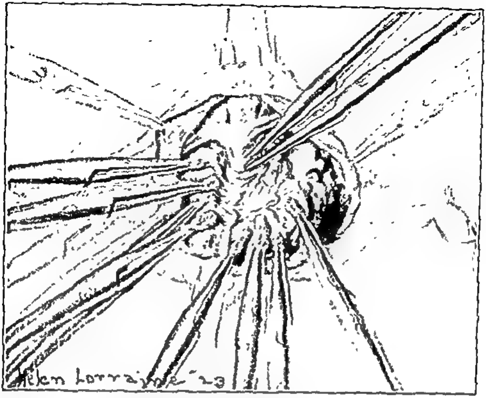

Fig. 332 —The thyroid isthmus is divided and the left lobe of the gland is dissected from the trachea for a short distance. The superior thyroid vessels are divided and ligated, thus liberating the upper portion of the gland.

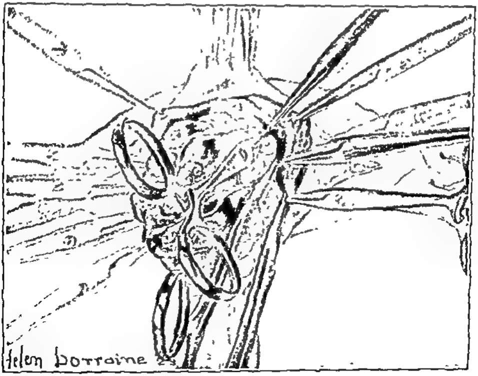

Fig 333 —The vessels are clamped along the proposed line of section of the gland The greater portion of the lobe is removed; only a small posterior segment is left.

tissue are dissected up to the level of the larynx and down to the sternal notch (Fig. 321), a perpendicular incision is made in the fascia, the prethyroid muscles are separated, and the false capsule of the thyroid gland is incised (Fig. 331). If this procedure does not give sufficient exposure, the prethyroid muscles are divided transversely. The upper pole and the superior thyroid vessels are mobilized, the vessels are grasped in three clamps, divided between the lower two and doubly ligated. The veins at the lower pole are doubly clamped, divided, and ligated. The middle thyroid vein is next clamped, hemostats are placed at the proposed level of resection, and an incision is made just anterior to this row of clamps for a depth of approximately 1 cm. The isthmus is divided, the gland turned outward, and the remainder of the dissection carried out from the tracheal side (Figs. 332 and 333). During the excision of the gland small sharp-pointed hemostats are inserted just ahead of the line of the incision so that the vessels are clamped before they are divided. In this way no especial attempt is made to clamp individual vessels but the tissue is clamped and ligated en masse completely across the thyroid lobe (Fig. 334). This undoubtedly saves considerable time and possibly saves some blood.

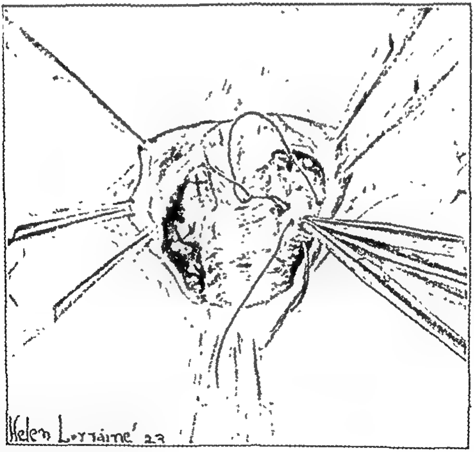

Fig. 334.—The bleeding is controlled by whipping over the points that are caught with hemostats with plain catgut in a needle, and the edges of the gland are approximated on each side of the trachea

Nordland and Larson advise ligation of the inferior thyroid arteries before the thyroid gland is exposed (Fig. 335). The regular collar incision is made and the skin flaps are dissected up to expose the prethyroid muscles. The medial border of the sternocleidomastoid muscle is freed in its lower mid portion, retracted outward, and the fascia of the prethyroid muscles is incised longitudinally at the lateral angle

of the incision over the sixth cervical vertebra. The outer edge is retracted laterally and the index finger is inserted and carried posteriorly until the transverse process of the vertebra is palpated. It is identified by the presence of a small tubercle. At this level the inferior thyroid artery is found running medially at a right angle to the carotid artery. Both inferior thyroid arteries are ligated before the pretracheal muscles are separated. Then both superior poles are ligated to control the major blood supply to the gland, thereby facilitating the operation. They state that there is no danger of interfering with the blood supply to the parathyroid glands by ligating all four arteries, and that parathyroid tetany will not result. This procedure would hardly seem to be necessary in the nontoxic or moderately toxic thyroids but should be of considerable value in operations on extremely vascular and friable glands.

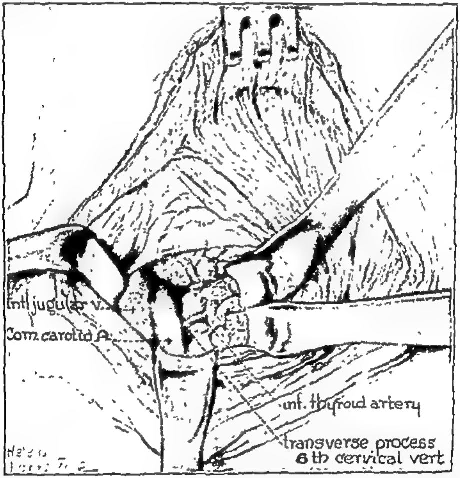

Fig 335 —Exposure of inferior thyroid artery at the level of the sixth cervical transverse process.

TOTAL THYROIDECTOMY

Total thyroidectomy is rarely done except for malignant disease.

The most important structures which may be injured in the performance of total thyroidectomy are the recurrent laryngeal nerves and the parathyroid glands.

The recurrent laryngeals are branches of the vagus nerves. The left one arises from the vagus within the thorax, curves around the arch of the aorta, and courses upward in the tracheoesophageal groove, posteromedial to the thyroid gland, to the larynx. The right nerve is given off by the vagus opposite the subclavian artery

and then passes upward and medially in the tracheoesophageal groove. These nerves, therefore, are in intimate contact with that portion of the thyroid gland which lies against the junction of the trachea and esophagus. They usually have been described as being separated from the posteromedial surface of the true capsule of the thyroid by the medial division of the false capsule which extends over the posterolateral surface of the gland and is attached to the trachea, thus being relatively well protected from trauma. Berlin describes certain important variations in this relationship between the thyroid gland and the recurrent nerves. He states that in about 10 per cent of cases this nerve passes through the substance of the gland, and in approximately 25 per cent of cases it passes through the fibrous attachment between the posteromedial surface of the gland and the lateral surface of the trachea immediately below the cricoid cartilage. At this point the thyroid is firmly adherent to the trachea by fibrous tissue, and where the nerve passes through this tissue there is great danger of injuring it during the separation of this portion of the gland from the trachea. The relationship between the recurrent nerves and the branches of the inferior thyroid arteries is also important. The nerve passes upward across this artery, either anterior or posterior to it. It is anterior to the vessel more frequently on the right side than on the left and, therefore, is more often exposed to injury on the right side when the branches of the inferior thyroid artery are ligated.

The parathyroid glands are inconstant in number, size, and position. They apparently may vary in number from one to eight, but as an average there are four, located in the region of the upper and lower poles of the thyroid, and usually separated from the true capsule of the thyroid by the inner layer of the false capsule. They vary considerably in color at different ages; in younger patients they are somewhat reddish-brown in color, gradually becoming brownish-yellow as age advances, and finally quite yellow in elderly subjects. Since the operation of total thyroidectomy is done usually in elderly patients, identification of the parathyroid glands should not be especially difficult. They may lie in close relationship to the thyroid gland, in some cases having been demonstrated on its lateral surface or actually within the substance of the thyroid. The inferior parathyroids are, as a rule, more definitely separated from the thyroid than the superior parathyroids.

The patient is placed in the dorsal recumbent position with the head of the table elevated slightly, the shoulders raised on a small flat pillow, and the head moderately extended. Patients with severe orthopnea ordinarily will be unable to stay in this position, but we have found that the administration of oxygen at frequent intervals or even continuously, if necessary, will make them comfortable and thus facilitate the operation.

The same type of collar incision is used for total thyroidectomy as for the subtotal operation. It is carried through the skin, subcutaneous tissue, and platysma. The cervical fascia, lying immediately beneath the platysma, should be divided, unless the operator plans to cut the prethyroid muscles. If it is to be divided, and dissected up with the platysma, it is best to ligate doubly and divide the anterior jugular veins, and then dissect the structures superficial to the ribbon muscles upward as far as the upper border of the thyroid cartilage and downward as far as the upper border of the sternum The sternohyoid and sternothyroid muscles are separated in the midline from the sternum to the insertion of the sternothyroid muscles above

In separating the muscles above the thyroid gland, special care must be taken to avoid injury to a small artery which passes down in the suspensory ligament of the thyroid, as it may retract and cause troublesome hemorrhage if divided before it is clamped. The ribbon muscles are retracted, the false capsule of the thyroid is divided in a perpendicular direction over the entire extent of the gland, and then dissected from the anterior surface of both lobes to the point at which the middle thyroid vein leaves them. This vein is doubly clamped, divided, and ligated. The inner division of the false capsule is entered at this level and is carefully and completely separated from the gland. This facilitates the exposure of the posterolateral border of the thyroid. The upper pole of the right lobe is exposed, the superior thyroid artery and vein are carefully dissected out, doubly clamped, divided, and the proximal ends are ligated. This is done on both sides as a preliminary procedure so that following ligation of the branches of the inferior thyroid artery on the right side, the blood supply to the gland will be diminished to the extent that the difficult dissection in the region of the tracheoesophageal groove may be carried out more easily. The right upper pole is then readily delivered and attention is turned to the lower lateral portion of the gland, where the middle thyroid vein is clamped, divided, and ligated. The inferior thyroid veins are next ligated and divided and the gland is rotated to the left to expose the branches of the inferior thyroid artery. This dissection is kept as close to the true capsule of the gland as possible, and the small branches of the inferior thyroid artery are clamped with small forceps and ligated with fine ligatures as the dissection proceeds. It is important to ligate the vessels as soon as they are divided because they are easily torn and if the clamps are pulled off accidentally the resulting hemorrhage obscures the field and may lead to injury to the recurrent nerve. When the lower pole is free, the gland is retracted anteriorly to expose its posteromedial surface which lies over the tracheoesophageal groove. While part of the gland is separated easily, that portion over the lateral surface of the trachea near the lower border of the cricoid cartilage is adherent, and since the recurrent nerve may pass through this area, it is important to proceed with special caution here. The dissection is carried to the junction of the anterior and left lateral surfaces of the trachea (*Fig. 336*).

At this time it is best for the surgeon to change to the left side of the operating table, as in this position he can gain a better view of the posteromedial surface of the left lobe of the thyroid during its removal.

The left upper pole whose vessels have been ligated is delivered and the operation is carried out as on the right side. When the branches of the inferior thyroid have been ligated the dissection is carried to the right until the original area of separation from the trachea is encountered, when the entire gland is removed. If there is a pyramidal lobe, it is apt to be located to the left and may extend up as far as the hyoid bone. Occasionally there will be no thyroid isthmus, the two lobes being entirely separate, as in some of the lower animals. Under such circumstances, there are apt to be bilateral pyramidal lobes which extend up to the hyoid bone (Fig. 337).

It is important in these cases that hemorrhage be controlled by ligation of the vessels with fine ligatures of either silk or fine cotton. Drains may or may not be used, as the operator desires. If indicated, they are placed in the lateral angles of the wound and should be removed within twenty-four to forty-eight hours. If the

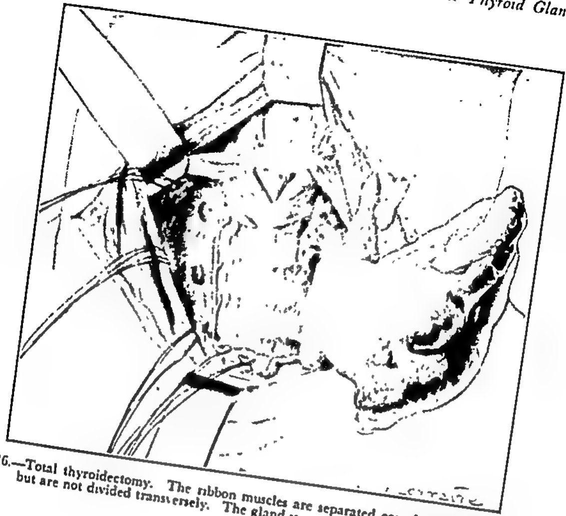

Fig. 336.—Total thyroidectomy. The ribbon muscles are separated completely in the midline but are not divided transversely. The gland is usually removed as a whole.

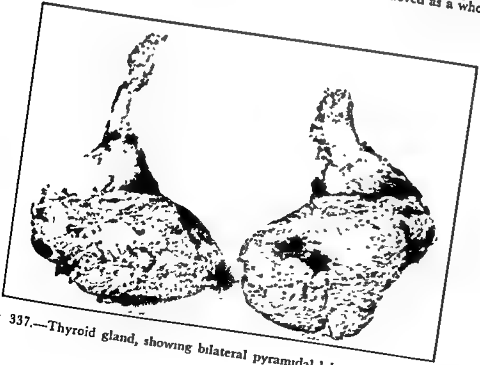

Fig 337.—Thyroid gland, showing bilateral pyramidal lobes and no isthmus.

ligatures and sutures are silk, drainage is usually unnecessary. After all bleeding has been controlled, the ribbon muscles of the neck and the platysma are approximated with interrupted sutures, and the skin is closed with interrupted sutures alternating with interrupted on-end mattress sutures of very fine silk.

When this operation is done for cancer of the thyroid gland, bilateral resection is rarely done. The indications for dissection of the neck have been discussed above, and when it is indicated the incision can be extended upward over the sternomastoid muscle and the radical procedure carried out.

INTRATHORACIC GOITER

Large intrathoracic adenomas are always serious surgical problems, and if there is evidence of tracheal compression, as often occurs, the difficulties of surgical removal are greatly increased Under such circumstances intratracheal anesthesia should be used. While the operation is in many respects similar to any thyroidectomy, there are certain technical points worthy of mention.

Since ample exposure is essential for a successful outcome in these cases, the incision should be longer than usual and the prethyroid muscles should be unhesitatingly divided The preliminary division and ligation of both superior and both inferior thyroid arteries, as recommended by Nordland and Larson, would seem especially appropriate here. If this is done, there will be little or no danger of hemorrhage during the intrathoracic manipulation of the gland. If the tumor is so large that it obviously will be difficult to deliver through the narrow superior thoracic aperture, trouble will be saved if the sternum is partially divided transversely at the level of the second costal cartilage or second interspace and split longitudinally. The segments of the sternum may then be well separated, thus giving considerably more room for the removal of the tumor.

As pointed out by Lahey, the dissection downward into the mediastinum should first be carried out posteriorly. When the separation of the tumor has been completed, it is grasped by tenacula and traction is made while the fingers are inserted into the mediastinum. Pressure against the gland and a lifting motion aid in the delivery.

After the removal has been effected, the cavity should be thoroughly inspected and any bleeding controlled Lahey packs the cavity with a gauze strip. Elevation of the foot of the bed following the introduction of a rubber tissue drain through the prethyroid muscles should make this unnecessary.

ABERRANT THYROIDS

Aberrant thyroid tissue may occur in various locations, as at the base of the tongue, anywhere along the tract of the thyroglossal duct, or in practically any location in the lateral neck region. When in the lateral neck region, these accessory nodules should be removed through a transverse incision, made if possible in one of the cervical creases. When they are beneath the angle of the jaw or beneath the upper mid portion of the sternocleidomastoid muscle, as often occurs, they are dissected out with ease. It must be remembered that the so-called lateral aberrant thyroid is often metastatic cancer, even when no grossly demonstrable lesion is

found in the lobe. When this condition is demonstrated by the pathologist, lobectomy and radical dissection of the neck must be done.

When thyroid nodules are discovered in the region of the foramen cecum or along the thyroglossal tract, it is important to determine whether or not thyroid tissue is present in the normal position before removing the aberrant thyroid. If the nodule at the base of the tongue is not sufficiently large to give obstructive symptoms, it is probably best to leave it. If it continues to grow until it causes obstruction, a portion or all of the nodule should be removed. Before doing a total removal, every attempt should be made to determine whether thyroid tissue is present in the normal position, even if this necessitates an exploration of the thyroid area. If none is present in the normal position, a small portion of the thyroid nodule at the base of the tongue must be left in place. These nodules are frequently quite vascular, and in some of the larger ones it may be wise to do a preliminary ligation of one of the lingual arteries before excising them

The patient is placed in Rose's position. The choice of anesthetic will depend on the size of the tumor and the degree of obstruction caused by it. Where there is marked obstruction, an inhalation anesthetic is contraindicated and the operation should be carried out under local anesthesia. Also, since either the high frequency knife or electric cautery is preferable to the scalpel, local anesthesia is ususally advisable.

After the area is anesthetized, a traction suture is placed through the tip of the tongue and an elliptical incision is made around the base of the tumor, which is then dissected out, a small portion of it being left in place, as indicated. The incision is closed with a deep layer of sutures to control hemorrhage and approximate the muscular portion of the tongue, and a superficial layer for the mucous membrane.

THE PARATHYROID GLANDS

Until a few years ago the parathyroid glands were of interest to surgeons only because they were exposed to injury in the course of operations upon the thyroid gland. But in 1926 Mandl removed a parathyroid adenoma from a patient suffering from osteitis fibrosa cystica, von Recklinghausen's disease, with complete relief of symptoms. Following his report of this case there have been numerous contributions to the literature of results obtained by the removal of both normal and abnormal parathyroid glands for such seemingly unrelated conditions as osteitis fibrosa cystica, ankylosing polyarthritis, and Paget's disease. The results following removal of normal parathyroids in such a condition as ankylosing polyarthritis are probably unsatisfactory, but the results following the removal of parathyroid adenomas and hyperplastic parathyroid glands from patients with the clinical and laboratory findings characteristic of hyperparathyroidism are extremely satisfactory. It would seem therefore that, for the present, parathyroidectomy should be advised only when the clinical and laboratory data are clearly indicative of hyperfunction of these glands.

The parathyroid glands have been found in numbers varying from one to eight, and in locations from the larynx to the mediastinum. However, the majority of

them are found in relation to the dorsal surface of the thyroid gland. They may also vary considerably in size, the usual size and shape being very much that of a small bean, and the color varies from a yellowish- or reddish-brown in young adults to an almost pure yellow in some elderly individuals. When adenomas develop, the characteristic shape is apt to be lost but the color remains unchanged, while the hyperfunctioning hyperplastic glands seem to retain both the characteristic color and shape.

According to Churchill and to Walton parathyroid adenomas seem particularly prone to gravitate downward into the mediastinum, those developing around the inferior pole descending into the anterior mediastinum, and those in the region of the superior pole, into the posterior mediastinum. Churchill states that the region of search for a parathyroid tumor should be the spaces bounded posteriorly by the deep cervical fascia resting on the anterior surface of the longus colli muscles, anteriorly by the mid-cervical fascia, above by the pharynx, and extending below to an unknown distance into the mediastinum.

Infiltration anesthesia may interfere with the dissection necessary to locate these tumors and the procedure may be too prolonged to use it, and, therefore, *general anesthesia through an intratracheal tube is indicated for these cases.*

The patient is placed in the dorsal recumbent position with a small flat pad under the shoulders and the head moderately extended. After the usual skin preparation and the application of sterile drapes, a low collar incision is made and the pretracheal muscles are exposed, as in thyroidectomy. The cervical fascia, however, should be left in place, and the muscles should be sectioned transversely at about the level of the thyroid isthmus. The false capsule of the thyroid gland is then incised and dissected away until the point is reached where the middle thyroid veins leave the gland. These veins are doubly clamped and divided and the inner layer of fascia followed around to its attachment to the trachea. The dissection from that time on must be done with care to avoid hemorrhage with resulting staining of the tissues If the tissues are allowed to become grossly blood-stained, there will be more danger of injury to the recurrent nerves and more difficulty in identifying the parathyroids. The region dorsal to the thyroid gland should be carefully examined for nodules, and if necessary the branches of the inferior thyroid artery are carefully divided and ligated and the posterior surface of the lower pole is exposed. The dissection is then extended, if necessary, to the region between the trachea and esophagus and also posterior to the esophagus Both the anterior and posterior portions of the superior mediastinum should be carefully palpated by insertion of a finger downward along the trachea and esophagus. If a tumor is discovered within the mediastinum, it should be gently withdrawn into the neck, the pedicle divided between clamps, and the tumor removed. Since the pedicle always contains branches from one of the thyroid arteries, it will be found to arise in the neck.

If, after careful search, no tumor can be located, the resection of one lobe of the thyroid gland may be justifiable if it contains a nodule, as there is the possibility of the complete inclosure of a parathyroid tumor by thyroid tissue

The finding of one tumor does not necessarily rule out the presence of another, as two of them have been found in several cases. The question of whether to look for another tumor when one has been demonstrated must be decided on the basis

of the size of the one seen, the degree of hyperparathyroidism present, and the general condition of the patient. It is important that at least one normal parathyroid gland be seen before complete removal of a tumor. If after a careful search none can be found, a small segment of the tumor should be preserved in place and its position marked so that if further symptoms should develop it can be easily located and removed.

Churchill has reported three cases showing diffuse hyperplasia and enlargement of the parathyroid glands associated with hyperparathyroidism, and in each of them he removed all save one gland, with satisfactory results. He strongly advises against removal of normal parathyroids when the clinical and laboratory evidence both point to hyperparathyroidism, as one may be almost certain under such circumstances that an adenoma is present. Removal of normal parathyroids will not give *relief and will only increase the difficulty of subsequent attempts to remove the tumor.*

The closure in such cases is very much the same as that following a thyroidectomy. Drainage should not be used if the field is dry, and it is extremely important that complete hemostasis should be obtained.

One of the chief dangers in operations on the parathyroids is injury to the recurrent laryngeal nerves. If there is difficulty in locating the enlarged parathyroid glands, it is probably wise to expose the recurrent nerves carefully so as to have them under direct vision during the operation.

PARATHYROID TRANSPLANTATION

One or more parathyroid glands may be removed during the course of a subtotal thyroidectomy; in total thyroidectomies there is even greater danger of this happening. Lahey, Crile, and others recommend the careful inspection of all thyroids under sterile technic by an assistant immediately after removal and the reimplantation of parathyroids so discovered. Lahey carefully removes all thyroid tissue and places the small gland in an opening in the sternocleidomastoid muscle, while Crile carefully preserves the portion of thyroid in contact with the gland and implants the combined tissue in muscle.

There have been occasional successful parathyroid transplantations recorded, but the majority of such attempts apparently have failed. For this reason, the work being done by Stone in the development of a special technic for such tissue transplants has occasioned a great deal of interest. It would seem that by this technic, which includes growing tissue cultures of parathyroid in the blood serum of the prospective host, the chances for successful transplantations are greatly increased.

LINGUAL THYROIDECTOMY. CERVICAL APPROACH

I. A. Bigger

Under endotracheal anesthesia a transverse incision is made in a cervical crease at the level of the hyoid bone (Fig 338, *A*). The skin and subcutaneous tissue are elevated from the line of incision to the inferior border of the mandible, the platysma being left in place to protect the inframandibular branches of the facial nerves. The anterior borders of both sternomastoid muscles are freed up at the

level of the bifurcation of the carotid arteries and both external carotid arteries are dissected out and traction ligatures are placed around them for temporary occlusion.

Incision is then made in the midline from the hyoid bone to the mandible. The mylohyoid and geniohyoglossus muscles are separated in the midline and the thyroid mass is exposed. The external carotid arteries now are temporarily obstructed by traction on the loops placed for that purpose (Fig. 338). The thyroid mass can be excised, subtotally or totally, in a dry field. The loops on the external carotid arteries are released one at a time, and bleeding vessels are clamped and tied. The wound is closed in layers with interrupted sutures of fine silk or cotton.

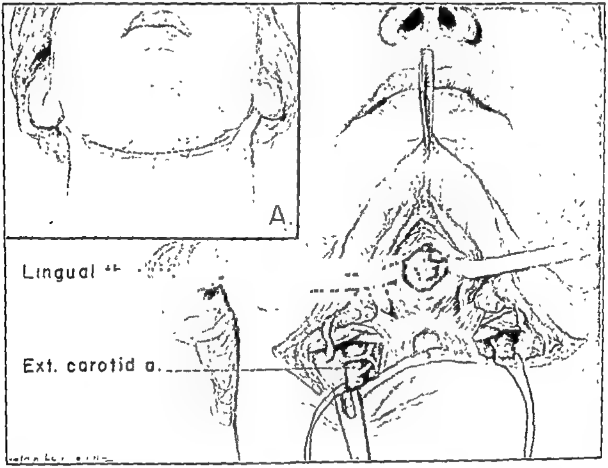

Fig. 338.—External approach for removal of lingual thyroid. Note traction ligatures around the external carotid arteries. Inset (*A*) shows line of the incision and position of the patient's head.

By using this approach, the operation may be performed in a dry field and without contamination of the wound by mouth organisms. Total or subtotal excision of the thyroid mass should be decided upon depending on the presence or absence of thyroid tissue in the usual location. This may be determined by the use of irradiated iodine, thereby avoiding the need for making a surgical incision in the lower cervical region.

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CHAPTER 28

TRACHEA AND LARYNX

PETER N. PASTORE

TRACHEA

Operations upon the trachea may be performed for the relief of asphyxia due to obstruction of the upper air passages, for the removal of foreign bodies and tumors, and as a preliminary procedure to operations upon the tongue, pharynx, or larynx. The type of operation will depend to a considerable extent upon whether it is performed as a deliberate procedure preliminary to some other operation on the upper respiratory tract or as an emergency measure.

Tracheotomy

The choice of anesthesia for tracheotomy is determined by individual circumstances One or 2 per cent procaine solution infiltrated in the operative site is used most often. In patients with obstructions of the upper air passages, the administration of oxygen during the operation is necessary. The introduction of an endotracheal tube or bronchoscope through the obstructed site permits the administration of adequate oxygen and supplementary anesthesia and makes it possible for the surgeon to proceed in an orderly manner.

A planned or nonurgent tracheotomy may be performed through a transverse or vertical incision. A transverse incision at the level of the upper border of the isthmus of the thyroid gland, which overlies the third and fourth tracheal rings, gives a satisfactory exposure and a much less unsightly scar. The incision, centered over the midline, should be from 2 to 6 cm. in length, depending on the depth and size of the trachea. The ribbon muscles are exposed and separated from the superficial structures, including the deep fascia, for a distance of 2 to 5 cm. in a perpendicular direction The prethyroid fascia is incised and the thyroid isthmus is exposed and retracted downward or divided between two clamps. The latter is generally preferred, for it gives a wider exposure of the trachea. If conditions permit, all bleeding vessels should be carefully clamped and ligated before the trachea is entered The divided ends of the thyroid isthmus also should be ligated

When the operation is performed as an urgent emergency, it is better to make an incision from the cricoid cartilage down the midline of the neck, from 3 to 6 cm. in length, as indicated. By making a vertical incision it is possible to save considerable time, as undercutting of the superficial structures is unnecessary. The second or third tracheal ring is divided in the midline and a tracheotomy cannula is inserted. Bleeding should be carefully controlled at this stage of the operation to avoid the aspiration of blood into the tracheobronchial tree Care should be taken

to clamp and ligate all bleeding vessels; otherwise, the coughing and straining usually associated with tracheotomy may cause them to open up. Some operators prefer to remove a disc of cartilage the size of the cannula to be inserted. This method has advantages where a large cannula is to be worn permanently. The removal of a large segment of a tracheal ring is to be avoided in infants because of the danger of tracheal stenosis or partial stricture after decannulization.

Tracheotomy wounds may be closed with widely spaced interrupted silk sutures, but cervical and mediastinal emphysema are apt to occur if the wound is too tightly closed. A pad of gauze, several layers in thickness, split in the center for half its length, is placed underneath the cannula shield. A tape for retention of the cannula is then placed around the neck and tied with a secure knot.

Following tracheotomy, the air in the patient's room should be kept warm and moist. Loose moist gauze may be kept over the tracheotomy tube, and, if a regular tracheal cannula is used, the inner cannula should be removed and cleansed at regular intervals and also whenever mucus accumulates in it. A rubber catheter should be inserted through the cannula into the trachea for removal of mucus by suction as necessary.

Tracheotomy wounds heal upon removal of the tube unless it is left in sufficiently long to permit the skin and tracheal mucosa to become continuous. When this occurs, the opening will not close spontaneously. When it is necessary to close such a fistula, the scar is dissected out, the wall of the trachea is infiltrated with procaine containing epinephrine, and the edges of the fistula are excised. If there has been no destruction of tracheal rings, the edges should be readily approximated.

When stricture of the trachea develops following the prolonged wearing of a tracheotomy tube, the problem is more difficult. Crile recommended resection of the strictured area and reunion of the tracheal ends by sutures of silver wire which included the tracheal rings, above and below the line of incision. He used three of these sutures, placing one on each side and one in front. The ends of these sutures were left long so that they could be brought out of the wound. This is a useful operation but can be carried out satisfactorily only if the trachea is relatively normal above and below the strictured area.

When cicatricial stenosis of the trachea and larynx occurs simultaneously, insertion of a radiopaque acrylic resin O'Dwyer tube, as described by Woodward, is probably the most satisfactory method of treatment.

LARYNX

External operations upon the larynx are usually done for carcinoma, either primary in the larynx and completely confined to it (intrinsic), or arising in adjacent structures and spreading to the larynx (extrinsic). The latter tumors as well as those which arise in the larynx and spread to other structures give a poor prognosis when treated by surgery alone.

Cicatricial stenosis of the larynx is usually corrected through an external approach if the obstruction is below the vocal cords. Occasionally large benign growths or foreign bodies are best handled through an external incision. Thyrotomy is useful for malignant tumors when they are confined to the mid portion of one cord and are of a low grade of malignancy Jackson states that a high degree of malignancy is not a contraindication to laryngofissure, if the growth is intrinsic

and of small extent. Laryngofissure is contraindicated in extensive tumors and in those located in the anterior and posterior parts of the larynx.

The two laryngeal operations most frequently carried out through external incisions are thyrotomy, or laryngofissure, and laryngectomy. Careful attention to the hygiene of the mouth and the administration of antibiotics before and after such operations minimize the danger of serious infection in the neck, and better healing of the wound usually is obtained, especially following laryngectomy.

Thyrotomy

Anesthesia for thyrotomy or laryngofissure is best obtained by the local infiltration of 1 or 2 per cent procaine solution in the line of incision and the topical use of 5 or 10 per cent cocaine solution, on bronchoscopic sponges, applied to the mucous membrane of the larynx. General anesthesia is not necessary but may be advisable in exceptionally long operations or in apprehensive patients.

A midline incision is made from the hyoid bone to the sternal notch. Dry dissection is then carried down to the cartilage but is done in such a manner that skeletonizing the cartilage is avoided. Some operators prefer to perform a tracheotomy at this stage, others do not utilize it during the operation. The cricothyroid membrane is incised transversely, which permits the introduction of cocaine sponges into the larynx. The external perichondrium is incised in the midline and the cartilage is sectioned with a circular saw or knife, but the internal perichondrium is left intact if the operation is for carcinoma Care must be exercised not to injure the cartilage as it is separated to permit dissection beneath the internal perichondrium until retractors can be inserted. The growth is then excised with a wide margin of normal tissue. When all bleeding has been controlled, the wound is closed with interrupted 00 chromic catgut sutures placed so as to avoid damage to the thyroid cartilage. The skin is approximated with silk or cotton sutures and a comfortable dressing is applied.

The aftercare of the thyrotomy patient is directed toward the relief of severe cough due to possible bleeding or excessive mucus. If a tracheotomy cannula has been used, it should be removed as soon as it can be demonstrated that it is no longer necessary If the patient has difficulty swallowing postoperatively, a tube should be introduced through the nose into the stomach for feeding.

Laryngectomy

Complete laryngectomy may be performed in one or two stages The two-stage operation is used when tracheotomy is necessary for the relief of laryngeal obstruction or when the patient's physical condition contraindicates an immediate major procedure. Formerly, the larynx was skeletonized and the wound was packed with gauze a few days prior to laryngectomy in order to decrease the chances of infection extending down into the mediastinum The antibiotics have made this unnecessary.

The surgeon has a wide choice of anesthesia for performing laryngectomy. Many operators prefer procaine infiltrated in the tissues of the neck, supplementing it, when necessary, with inhalation, intravenous, or rectal anesthesia. Other surgeons routinely employ cervical block anesthesia. Total laryngectomy is indicated in many intrinsic malignant tumors of the larynx not suitable for laryngofissure.

It may also be indicated when extrinsic tumors involve the larynx, as, for example, when a tumor arising from the lower portion of the anterior wall of the hypopharynx invades the larynx. Laryngectomy is still indicated when intrinsic laryngeal tumors spread outside the larynx, if it appears that it is possible to remove all of the tumor tissue along with the larynx. A tumor which has extended to the point where it is obvious it cannot be removed completely is usually best treated by irradiation.

Tumors of the larynx rarely metastasize to the cervical lymph nodes as long as they remain intrinsic, but when such tumors spread beyond the confines of the larynx they are found to spread to the regional lymphatic structures, and excision of the regional lymphatic-bearing tissue is indicated, either at the time of laryngectomy or as a secondary procedure after the patient has recovered from the laryngectomy.

Total laryngectomy is best performed through a perpendicular incision extending from just above the hyoid bone down the midline of the neck to the level of the sternal notch. This incision has almost entirely replaced the T-shaped incision formerly used. It is carried through the skin, subcutaneous tissue, and between the ribbon muscles of the neck. The larynx and the upper one or two rings of the trachea are skeletonized anteriorly and laterally as indicated It is important, however, not to dissect the tissues away from the trachea anteriorly and laterally below the level of the first or second ring, as this may interfere with their blood supply. After the larynx has been skeletonized, the trachea is divided, either between the cricoid cartilage and the first tracheal ring, or between the first and second tracheal rings, as indicated by the disease. It is extremely important to control hemorrhage before the trachea is opened so as to avoid the aspiration of blood.

Before dividing the trachea, 2 per cent procaine solution with epinephrine is injected between the tracheal rings beneath the mucosa and a small amount of 2 per cent cocaine solution is sprayed through a small needle into the lumen of the trachea to anesthetize the mucosa When the tracheal mucosa is sufficiently anesthetized, the trachea is divided and then fitted with a suitable-sized tracheal extension tube for the administration of supplementary anesthesia if necessary. The larynx is lifted upward and forward and separated from the esophagus to the level of the arytenoid cartilages, then allowed to fall back into place. An incision is then made through the thyrohyoid membrane, and the tumor is inspected, especially with regard to its upward extension. After the upper limit of the tumor has been determined and the level of excision of the larynx decided upon, the pharynx and mouth are packed with gauze through the opening in the thyrohyoid membrane, so as to prevent gross contamination of the wound from the mouth and pharynx. Excision of the larynx is then completed, care being taken to leave as much of the anterior wall of the hypopharynx as is justified by the location and extent of the tumor.

It is desirable to divide the thyrohyoid membrane immediately above the thyroid cartilage if the tumor does not extend too near this level. If the tumor is extensive and has invaded the posterior wall of the larynx and thereby involved the anterior wall of the hypopharynx, it may be necessary to excise a considerable portion of this wall, but the subsequent closure of the wound in the hypopharynx is thus made more difficult and altogether less satisfactory.

After the larynx has been excised, the opening in the hypopharynx is closed, *usually in the form of a T, V, or U,* as this causes less narrowing of the hypopharynx and upper esophagus and thus offers less chance of subsequent stricture formation. The closure should be made with interrupted sutures of 00 chromic catgut. Before the last sutures are tied, the gauze is removed from the mouth and pharynx, the mucous membranes of the mouth, pharynx, and nasal cavities are carefully cleansed, and a nasal tube is passed downward and directed through the opening in the hypopharynx into the esophagus and on into the stomach. It is usually desirable to place a second row of interrupted sutures of the same material as used for the first row. The trachea is sutured to the skin margins with interrupted sutures of fine silk. Before this is done it is desirable to trim away the subcutaneous fat so that more accurate approximation may be obtained. Drains are rarely required, but, if it seems desirable, a drain may be inserted in the midline or through a small stab wound to the side of the main incision. A dry gauze dressing is placed over the wound and a few turns of bandage are passed around the neck above the laryngectomy stoma or cannula.

Postoperatively a liquid diet with adequate vitamin, protein, and caloric content is administered by tube. The tube is removed after the seventh postoperative day, when the patient usually is able to swallow easily. Semisolid foods usually are tolerated after approximately ten days.

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CHAPTER 29

THE THORAX

Frank Philip Coleman

THE SURFACE ANATOMY OF THE CHEST

The thoracic cavity is completely divided into right and left sides by the mediastinum, which extends from the thoracic inlet above to the diaphragm below, and from the posterior surface of the sternum in front to the spine in the back. The right pleural cavity is slightly larger than the left because the heart occupies a greater amount of space to the left of the midline. The right anterior pleural reflection crosses the first rib near the right border of the sternum and inclines downward and inward, passing beneath the sternal border at the middle of the manubrium, then downward beneath the mid portion of the sternum to the level of the sixth costal cartilage, where it becomes continuous with the right costodiaphragmatic reflection. On the left side the anterior reflection is approximately the same as the right as far down as the level of the fourth costal cartilage, where it deviates to the left, being about 2 to 3 cm. from the left border of the sternum at the level of the fifth interspace. It then passes downward to the sixth costal cartilage at approximately the same distance from the left border of the sternum, where it becomes continuous with the left costodiaphragmatic reflection. The costodiaphragmatic reflections take approximately the same course on the two sides except that the right is slightly higher. Both reflections start at the level of the mid portion of the xiphoid and pass outward and downward through the eighth costochondral junction in the midclavicular line to the lower border of the tenth rib in the midaxillary line. They then pass downward and backward, and then inward to the lateral border of the sacrospinalis muscles, from which point they go slightly upward to the spine.

The lungs do not extend as far forward and downward as the pleural cavities except during forced inspiration The main interlobar fissure begins posteriorly and medially on both sides at the level of the tip of the third spinous process and extends outward, then outward and downward across the scapula, and then downward and forward, crossing the fourth rib between the lateral border of the scapula and the posterior axillary line, the fifth rib between the posterior and midaxillary lines, and the sixth rib in front of the midaxillary line, terminating at the lower border of the sixth rib in the nipple line. On the right side, the minor fissure (between the upper and middle lobes) branches off from the main fissure at the fourth interspace just in front of the posterior axillary line and follows the fourth rib forward to the sternum.

The superior border of the heart (clinically, the base) lies across the sternum at the level of the third costal cartilage, projecting beyond the sternum for about 2.5 cm. on each side. The inferior border extends from the lower edge of the right fifth costal cartilage, about 2.5 cm. lateral to the sternum, downward and to the left across the base of the xiphoid to the left fifth interspace or upper border of the left sixth costal cartilage about 5 cm. from the sternum. The right and left borders are represented by slightly convex lines, the right being more convex than the left.

The ascending aorta has its origin at the level of the upper border of the third costal cartilage behind the mid portion of the sternum and extends upward and to the right to the first interspace near the right sternal border. The superior vena cava lies in front of the ascending aorta and to the right, and the pulmonary artery lies to the left and slightly posterior to the aorta. There are two main coronary arteries, the right and left. Both of them have anterior and posterior divisions; the left anterior division is located at the interventricular groove near the left border of the heart, and the right anterior division goes downward and slightly to the right from the anterior surface of the base of the aorta near the right auriculoventricular line.

The internal mammary arteries arise from the subclavians posterior to the inner ends of the clavicles and pass downward on the pleura at a distance of about 2 cm. from the sternum, diverging slightly as they descend Each artery is usually accompanied by two veins. At the sixth intercostal space they divide into the musculophrenic and the superior epigastric arteries. They give off pericardial branches in their first portion and anterior intercostals opposite each interspace The posterior intercostal arteries are given off from the aorta opposite the interspaces and pass outward underneath the lower borders of the ribs.

The intercostal nerves run below the lower border of the ribs in the intercostal spaces beneath the external intercostal muscles and give off the lateral cutaneous nerves in the axillary line. The lower five intercostal nerves are distributed to the abdominal wall.

MEDIASTINUM

The fascial planes of the neck communicate directly with the mediastinum, and this must be considered in the gravitation of infection from the cervical region or the passage of air from the mediastinum to the neck. The division of the mediastinum into anatomical compartments is useful in the descriptive localization of intrathoracic lesions.

Callander divides the mediastinum into anterior and posterior divisions, the line of division passing in front of the trachea. He further divides the anterior mediastinum into superior and inferior parts, the line of separation passing through the junction of the superior and middle segments of the sternum. The superior part of the anterior division contains the thymus gland and the great vessels, and the inferior part contains the pericardium, heart, and the origins of the great vessels In the posterior mediastinum are the trachea and main bronchi, the esophagus, the descending aorta, the thoracic duct, the azygos veins, and the vagus and sympathetic nerves

The esophagus, upon entering the superior aperture of the thorax, lies on the anterior surface of the bodies of the vertebrae a little to the left of the midline. It

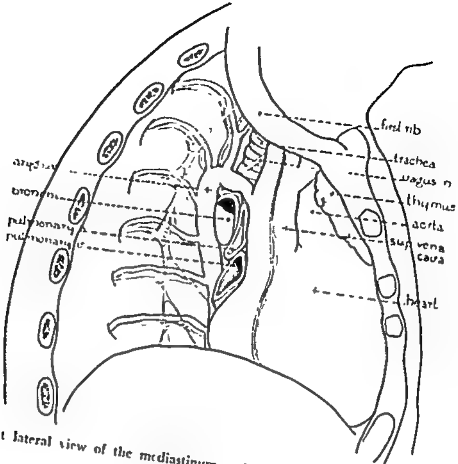

Fig. 339.—Right lateral view of the mediastinum and hilum of the lung. (Redrawn from Spaltheholz.)

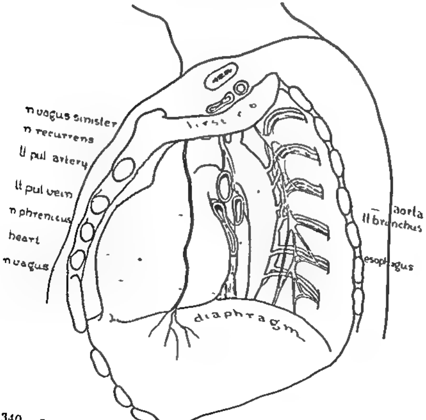

Fig. 340.—Left lateral view of the mediastinum and hilum of the lung.

then deviates slightly to the right, lying a little to the right of the midline at the level of the fifth dorsal vertebra, but at the level of the seventh dorsal vertebra it again inclines to the left. The descending aorta lies to the left of the esophagus and posterior to the trachea and main bronchi. Because of the position of the aorta, the thoracic esophagus, *except the extreme lower portion, is best approached from* the right.

The trachea occupies the mid portion of the upper mediastinum between the ascending aorta anteriorly and the esophagus posteriorly as far down as the junction of the upper and middle segments of the sternum, where it divides to form the right and left primary bronchi (Fig. 339).

The right vagus nerve passes downward on the lateral surface of the trachea and after giving off branches to the pulmonary plexus passes posterior to the hilum of the right lung. The left vagus nerve passes downward in front of the arch of the aorta and then to the posterior surface of the hilum of the left lung. The phrenic nerves lie anterior to the vagi, the right one passing down on the right lateral surface of the superior vena cava on to the pericardium and then downward on the right surface of the pericardium to the diaphragm; the left passes downward across the anterior surface of the upper portion of the ascending aorta, across the base of the pulmonary artery, and then downward across the left side of the pericardium to the diaphragm. The thoracic sympathetic chains of ganglia lie on each side of the spine anterior to the heads of the ribs, underneath the pleura, and anterior to the intercostal vessels (Fig. 340).

The thymus gland lies between the upper portion of the sternum and the great vessels and trachea It is usually almost entirely replaced by fibrous and fatty tissue by the time of adult life.

PHYSIOLOGY IN RELATION TO THORACIC SURGERY

There is probably no part of the body in which a knowledge of physiology is more important to the surgeon than the thorax. This applies especially to the changes which occur with variations in intrathoracic pressure. The pleural cavities are normally filled by the lungs except for that space occupied by the small amount of fluid for lubrication of the pleural surfaces. When the lungs are collapsed, as when air is allowed to enter the pleural space, they are considerably smaller than the cavities which they normally fill. They are therefore constantly distended, and, since they contain elastic tissue which tends to pull them away from the chest wall, there is a negative intrapleural pressure, which averages about 6 to 8 cm. of water during inspiration and 3 to 5 cm. of water during expiration. This negative pressure is of great importance in respiration and also in the circulation of the blood. When an opening occurs in either the chest wall or the lung, permitting air to enter the pleural cavity, the lungs become partially deflated, the degree of deflation depending on the size of the opening and also on whether there is free passage of air from within as well as from without. The intrapleural pressure in open pneumothorax does not become greater than atmospheric pressure, and in the spontaneous closed pneumothorax the pressure usually is less than that of the atmosphere, but in valvular or tension pneumothorax the intrapleural pressure may become considerably greater than atmospheric pressure, especially during expiration If this occurs in the absence of either pleural adhesions or fixation of the

mediastinum, marked respiratory and circulatory embarrassment will result. The normal negative pressure of the auricles and the great veins is replaced by positive pressure which interferes with filling and decreases cardiac output.

Because of the complicated relationship between the action of the chest wall and the diaphragm, it is extremely difficult to determine accurately the part played by each in respiration, but it is probable that expansion of the chest wall is responsible for 60 to 70 per cent of the increase in the size of the lungs during inspiration, and contraction of the diaphragm for the other 30 to 40 per cent. The peripheral portion of the normal lung is so perfectly elastic that it is probable that contraction of the diaphragm affects all parts of it nearly equally, and the same is true of expansion of the chest wall. Bigger and Cox showed experimentally that contraction of the diaphragm had approximately the same effect on the bronchi of the upper and of the lower lobes, and it seems justifiable to assume that this would apply also to the parenchyma of the lungs. While this is apparently true of normal lungs, pleural adhesions would obviously tend to limit the effect on that portion of the lung most distant from the diaphragm; and fibrosis of the lung, by decreasing its elasticity, would have much the same effect.

By the vital capacity of the lungs we mean the greatest amount of air which can be expired after a maximum inspiration. This varies with the size and vitality of the individual but may reach as much as 6,000 c.c. and, in exceptionally vigorous persons, even more. The tidal air is that amount taken in during a normal inspiration and averages around 500 c.c. It is evident, therefore, that the capacity of the lungs is approximately ten times that necessary to carry on normal respiration when the body is at rest. The same principle applies to other organs of the body, as the kidneys, liver, etc. With this great excess in lung capacity, one would expect to find that complete collapse or even complete removal of one lung would hamper the individual very little except under conditions of stress, and this has been proved correct, both experimentally and clinically.

There is a vast difference in the effect produced by closed and open pneumothorax. In closed pneumothorax a certain amount of lung tissue is collapsed and thereby made inactive as far as respiration is concerned, but an otherwise normal individual can easily compensate for this by increasing the depth and rate of the respirations. As stressed by Graham, the amount of lung tissue which can be collapsed without causing serious symptoms will depend to a large extent on the individual's vital capacity. It is important, therefore, to determine the vital capacity before collapsing a large amount of lung tissue. It should be emphasized that posture has a marked influence on the vital capacity, which ordinarily is measured while the patient is erect, the position in which it is greatest. It is less when the individual is in the dorsal recumbent position and still less in the prone position. It is important for the surgeon to bear this in mind when operating upon patients who already have a lowered vital capacity, and this is especially true when the thorax is to be opened.

Graham states that the important factors which determine the effect of open pneumothorax are the vital capacity, the mobility of the mediastinum, and the size of the opening in the chest wall If the mediastinum were a rigid partition between the two sides of the thorax, the normal person should be able to withstand an opening of any size in one chest wall without developing serious symptoms. But the

mediastinum is normally very mobile, so that when a sufficiently large opening is made in one chest wall, not only is the lung on that side collapsed but the contralateral lung is also affected, as a result of the shifting of the mediastinum to that side. When the vital capacity is normal, an opening in the chest wall of only moderate size may be readily compensated for by an increase in the depth and rate of respiration; but when the vital capacity is reduced, even a small opening may rapidly lead to asphyxia. One would naturally expect the size of the opening to have an effect on the seriousness of symptoms, and that this is true may be demonstrated readily. If a small cannula is inserted into each pleural cavity of a healthy dog, the animal will still be able to carry on without great respiratory difficulty; but if the cross-section area of the opening approaches the cross-section area of the lumen of the animal's larynx, dyspnea will develop and compensation will be difficult. The larger the opening the more rapid the onset of respiratory failure. With a large opening compensation can be maintained only for a short time.

Brunn has pointed out that during lobectomy, under local anesthesia, patients will usually have little respiratory difficulty so long as they breathe quietly, but if they breathe deeply, or cough, or become excited, they immediately become dyspneic and cyanotic. This is in accord with Brauer's idea, that so-called "penduluft" played a considerable part in the respiratory disturbances caused by open pneumothorax. He thought that the passage of air from the contralateral lung to the collapsed lung during expiration and then back during inspiration was an important factor in the respiratory upset. As a result of this constant to-and-fro shifting of air between the two sides, that which was inspired into the less collapsed lung contained less oxygen and more carbon dioxide than atmospheric air, and this, at least in part, accounted for the signs of asphyxia.

In most chronic inflammatory diseases of the lungs, the mediastinum becomes more fixed as a result of adhesions and inflammatory thickening of the mediastinal pleura. When this is the case, collapse of one lung either by pneumothorax or by thoracoplasty may cause relatively little respiratory disturbance. It is important, however, that the functional capacity of the better lung be estimated before collapse of the diseased lung is undertaken.

The presence of a large opening in the chest wall not only causes profound disturbances in respiration and circulation, but also permits excessive heat loss. This is much greater when the pleura is opened than when the peritoneum is opened, because a greater surface area is exposed and the air in contact with the surface is being rapidly changed.

Pulmonary collapse affects the circulation of both blood and lymph. The return of blood through the great veins to the right side of the heart is greatly facilitated by the negative intrathoracic pressure, and when this becomes less negative (nearer atmospheric pressure), an elevation of venous pressure results. Change in the degree of tension in the lung, as a result either of collapse or of overdistention, diminishes the flow of blood through that lung, and this in turn shunts a greater amount of blood through the opposite lung. Graham and Brock and Blair have shown that pulmonary collapse decreases the flow of lymph in the collapsed lung and this probably has an important part in the rapid subsidence of fever and other evidences of toxicity when a diseased lung is collapsed.

FACTORS INFLUENCING THE DEVELOPMENT OF THORACIC SURGERY

Many factors are responsible for the great advances made in thoracic surgery during the past few decades. The fact that surgery of this region had lagged behind that of other parts of the body acted as a challenge to a large group of surgeons and investigators. As a result, the pathologic physiology of the thorax, especially that associated with open pneumothorax, has received particular attention. With a better appreciation of the effects of open pneumothorax, methods were found by which many of the undesirable results could be prevented. The first development along this line was Sauerbruch's negative pressure chamber. Then came the positive pressure chamber, and then the development by Meltzer and Auer of simpler methods for the intratracheal administration of anesthetics under positive pressure. Their contribution to the administration of anesthetics under positive pressure has probably been more responsible for the rapid development of intrathoracic surgery than any other single factor. Gale and Waters developed a method by which one of the main bronchi may be occluded by an especially devised intrabronchial catheter which permits the administration of the anesthetic into the good lung under the desired pressure, while it is shut off from cross contamination from the diseased lung. This method of giving anesthetics is not widely used but should be of especial value when the diseased segment of lung contains a large amount of pus which cannot be completely evacuated before the thorax is opened.

Crafoord of Stockholm, Sweden, perfected a machine and a technic for the administration of anesthetics, which are of proved value in thoracic surgery. By this technic it is possible to control both the rate and volume of the respirations, and it appears that one is able to perform the more prolonged intrathoracic operations with less serious blood chemical changes than occur when the conventional methods of anesthesia administration are used.

Progress in thoracic surgery also depended on the development of more accurate methods of diagnosis and localization, both of which are essential when surgery is to be employed. The development of roentgenography and fluoroscopy and the formulation of contrast media, nonirritating to the tracheobronchial tree, have been of inestimable aid in thoracic surgery. The remarkable development of endoscopy has also been an important factor in the progress made in this field, especially in connection with excisional lung surgery. Thoracoscopy, developed by Jacobaeus and perfected by Matson and others, is of more limited value. In recent years, cardiac catheterization and serial roentgenograms following the intravenous or intra-arterial injection of radiopaque substances have made possible more accurate diagnosis and localization of cardiac and vascular lesions. Aortography has been of definite assistance in the differentiation of mediastinal tumors from certain vascular lesions.

The introduction of the sulfonamides and the antibiotics has had a profound influence on surgery, and especially on thoracic surgery. The use of these agents, alone or in combination, has had a large part in the striking reduction in the incidence of postoperative complications due to infection. Patients with advanced suppurative pulmonary disease may now be subjected to excisional surgery with far less risk and a much greater chance of complete recovery than formerly was the case.

Technical advances based on a more detailed knowledge of surgical anatomy also have had a part in the development of surgery of the lung, as well as in the surgical correction of certain cardiac and vascular defects. Intrahilar dissection of the structures of the lung root with individual ligation of the vessels and accurate closure of the bronchi was first used in pneumonectomy by Rienhoff in 1933. With this technic there was a marked decrease in the incidence of postoperative complications and in the mortality of pneumonectomy. In 1939 Blades and Kent and Coleman and Seastrunk independently applied the principle of individual treatment of the hilar structures to lobectomy for bronchiectasis and in subsequent reports demonstrated the superiority of this technic over methods previously used. Increasing experience with lobectomy for bronchiectasis showed that this disease frequently is limited to certain pulmonary segments which are amenable to individual excision. As early as 1939, Churchill and Belsey prophesied that the bronchopulmonary segment would replace the lobe as the surgical unit of the lung. Detailed anatomical studies of the lung, carried out by many investigators, showed that all the pulmonary segments are suitable for excision. Segmental resection permits the preservation of healthy lung tissue so that extensive bilateral disease, heretofore considered unsuitable for surgery, may now be successfully treated.

Finally, the improved general care of the patient, before, during, and after operation, has contributed to progress in thoracic surgery. The preoperative correction of hypoproteinemia, of vitamin deficiencies, and of anemia all are of special importance in the chronically ill patient. A better understanding of the importance of maintaining a proper acid-base balance has resulted in improved care of patients during prolonged anesthesia. This has resulted in greater care in the prevention and control of anoxia and carbon dioxide retention. These efforts are important in the prevention of such catastrophes as ventricular fibrillation and cardiac standstill. The judicious use of procaine intravenously also has helped prevent and control serious irregularities of cardiac rhythm A considerable blood loss can be anticipated during major thoracic operations and provision should be made to replace this loss, in so far as possible, as it occurs. A number of investigators have shown that an average of from 1,000 to 1,500 c.c. of blood is lost during pneumonectomy Blood loss following major thoracic operations should also be anticipated and replaced. Careful attention to evacuation of pulmonary secretions and the use of intratracheal suction or bronchoscopy whenever needed are of the utmost importance in the early postoperative period.

FRACTURE OF THE RIBS AND STERNUM

As a result of the great number of automobile accidents, injuries to the thoracic wall by blunt force are of frequent occurrence. The majority of these injuries are treated conservatively and do not require operative intervention. The most common trauma is fracture of one or more ribs.

Injury to the lungs is commonly the result of or is associated with fracture of the ribs. There may be extensive laceration of the lung or an entire lobe may show hemorrhagic consolidation The lungs, heart, or abdominal viscera may be torn by an in-driven rib fragment which recoils to its normal position, so that a roentgenogram may be misleading Displaced fractured ribs are usually accompanied

by some degree of intrapleural hemorrhage, and persistent intrapleural bleeding may result from laceration of the pulmonary, intercostal, or internal mammary arteries.

Trauma to the chest wall produces bronchospasm and increased bronchial secretions. Increased bronchial secretions, or the presence of blood in the bronchial tree, with associated bronchospasm and an ineffective cough, frequently terminate in pulmonary atelectasis.

In severe crushing wounds of the thorax, a large segment of the chest wall is depressed during inspiration and forced outward during expiration (paradoxical respiration) (Fig. 341). A normal negative intrathoracic pressure cannot be maintained and this may lead to inadequate cardiac filling and peripheral circulatory collapse. A flail chest wall, bronchospasm, and reduction of functioning pulmonary tissue by hemorrhage into the alveoli, and hemothorax or pneumothorax will lead to serious anoxia.

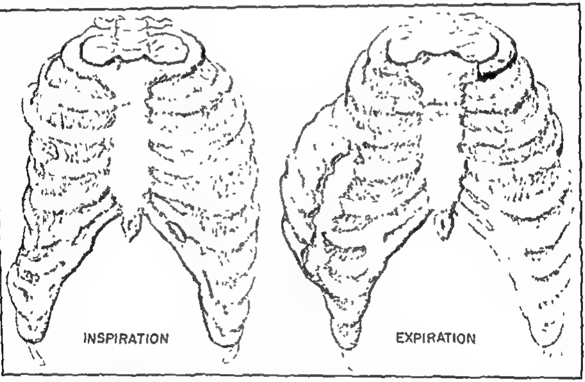

Fig. 341.—Displacement of fractured ribs inward during inspiration and outward on expiration or cough—paradoxical *respiration* (Coleman and Coleman, Surg., Gynec. & Obst., courtesy The Franklin H Martin Memorial Foundation.)

In general, the care of patients with fractured ribs should be directed toward the relief of shock and the correction of the altered intrathoracic physiology. Excessive tracheobronchial secretions are aspirated by an intratracheal catheter or if necessary by bronchoscopy. Distention of the neck veins indicates a rise in the venous pressure which may be due to compression of the heart by blood within the pericardium, to tension pneumothorax or massive hemothorax, or to mediastinal emphysema. It is essential that the cause of the rise in venous pressure be determined so that appropriate treatment may be instituted.

The pain associated with rib fractures is of primary importance, because of its adverse effect on respiration. Immobilization of the thorax and the administration

of opiates have been commonly used for the relief of this pain, but immobilization of the chest wall by external appliances of any kind is unphysiologic, since it further decreases pulmonary function and renders cough even more ineffective. Immobilization by strapping often increases the depression and angulation of the broken ribs, and this may lead to additional damage to the lungs or other internal organs. Opiates in sufficient dosage to relieve such pain depress the cough reflex and lead to the retention of bronchial secretions.

In 1933 Latteri recommended the injection of alcohol into the intercostal nerves for the relief of the pain associated with fractured ribs. Intercostal nerve block relieves pain and thereby improves pulmonary ventilation, and aids bronchial drainage. Improved bronchial drainage is the result of relief of bronchospasm and the increased effectiveness of cough. Uncomplicated fractures of one, two, or even three ribs often require no treatment other than intercostal nerve block.

For intercostal block the patient is placed in the lateral position with the scapula retracted anteriorly. If the fracture site is proximal to the angle of the rib, a paravertebral block is carried out. If the ribs are fractured anterior to the angles, the intercostal nerves are blocked at a point midway between the vertebral border of the scapula and the spinous processes. In addition to blocking the nerves accompanying the fractured rib or ribs, it is also necessary to block the intercostal nerves above and below the fractured ribs. Three to 5 c c. of a 1 per cent aqueous solution of procaine is injected into the region of each intercostal nerve, and this is followed by the deposition of 2 c.c. of procaine in peanut oil (2 per cent procaine, 5 per cent benzocaine in peanut oil) in and about each intercostal nerve.

Multiple, complete rib fractures require stabilization of the chest wall. This is necessary to correct disturbances in respiration and circulation and to prevent such complications as atelectasis, pneumonitis, and pulmonary abscess. Multiple rib fractures with marked paradoxical motion of the chest wall are the most direct indication for internal fixation of the fractured ribs. Complete fractures of the lower six true ribs anterior to the angles are especially prone to develop displacement and excessive mobility. Gratifying results may be obtained in these cases by exposure of the fracture sites and fixation with wire When fracture of the ribs with lung lacerations and associated massive hemothorax, tension pneumothorax, or mediastinal emphysema require operation for control of the associated conditions, it is advisable to wire the ribs at the same time. The operation is carried out under intratracheal anesthesia.

Anterior fractures of the upper five ribs are best approached by an anterior incision. The pectoral muscles are elevated and this gives an excellent exposure of the ribs and costal cartilages (Fig. 342). Posterior fractures of the upper five ribs are approached through a parascapular incision, the trapezius and rhomboid muscles being divided in line with the skin incision. Fractures of ribs six through ten are readily exposed by making the incision over the fracture site. When ribs six through ten are fractured both anteriorly and posteriorly, exposure is best obtained by a U-shaped incision (Fig. 343).

For satisfactory fixation of fractured ribs, the fragments must be fixed in two planes. Three methods of internal fixation by wire have been found dependable and adaptable to most types of rib fracture (Figs 344-346). In oblique fractures, stabilization is accomplished by on-end wiring, with a second wire suture placed in

a circumferential manner (Fig. 344). Transverse fractures of the ribs may be immobilized, either by overlapping the fragments or by an on-end approximation over a bone peg. Overlapping of fragments leads to shortening of the rib and is not adaptable to multiple fractures of a single rib (Fig. 345). Intramedullary pegging of transverse rib fractures accompanied by on-end wiring with No. 28 stainless steel wire gives fixation capable of withstanding the strain resulting from respiratory excursions, and even coughing (Fig. 346). Drill holes are made through the rib 2 cm. from the ends of the fragments. A suitable peg, 3 cm. in length, is cut

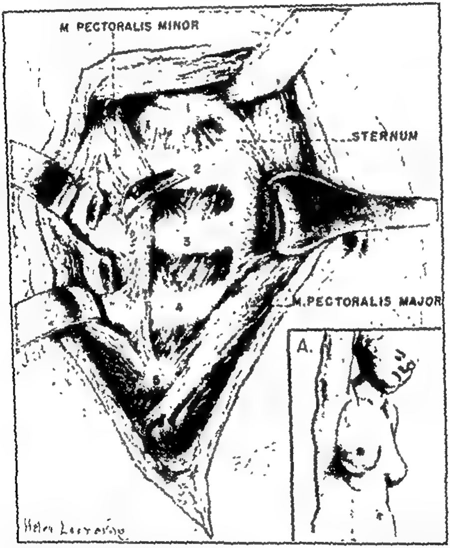

Fig 342.—Surgical approach to fractures of upper five ribs anterior to the midaxillary line (Coleman and Coleman, Surg., Gynec. & Obst.; courtesy The Franklin H. Martin Memorial Foundation.)

from the superior margin of a neighboring healthy rib. After tunneling with a hemostat the medullary cavity of the rib on each side of the fracture, the bone peg is introduced and the fragments are approximated over the bone graft by drawing taut the previously placed wire suture. The wire maintains alignment in the longitudinal axis while the bone peg prevents displacement in a transverse plane. Additional support to the site of fixation can be accomplished by bridging the intercostal bundles either over or under the fracture with interrupted sutures of cotton. This added support is especially important in the fixation of fractured cartilages.

Stripping the periosteum from the ends of the fragments is unnecessary and unwise for it may result in delayed union and, in case of infection, in sequestration of that part of the rib which is devoid of periosteum.

Fracture of the sternum usually may be reduced by placing the patient in the dorsal recumbent position, on a small sandbag or firm pillow at the level of the fracture. The arms are extended above the head, and, while traction is being applied to them, pressure is made over the anterior fragment. If there is marked displacement which cannot be reduced by closed manipulation, open reduction is indicated. This may be done under local anesthesia, the anesthetic solution being injected in the skin and subcutaneous tissue over the sternum, between the fragments, and into two or three interspaces on each side of the fracture. A midline

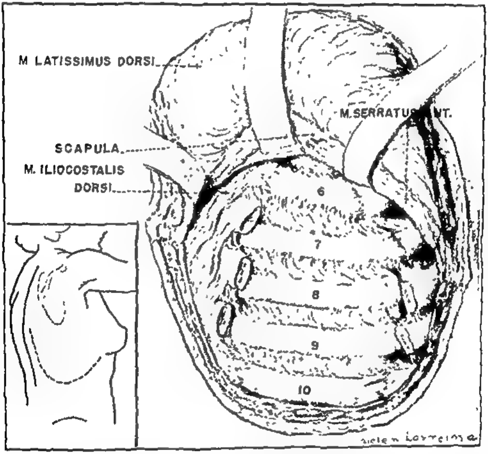

Fig 343 —Surgical exposure of anterior and posterior fractures involving ribs six through ten The musculocutaneous superior flap is reflected upward (Coleman and Coleman, Surg, Gynec. & Obst, courtesy The Franklin H Martin Memorial Foundation)

incision is centered over the fracture, extension is applied, and the fragments are brought as nearly into position as possible. An instrument, such as a heavy periosteal elevator, is then inserted between the ends of the fragments, and the anterior fragment is carefully forced back into place. Special care should be used to avoid inserting the instrument too deeply or letting it slip, thereby endangering important mediastinal structures In simple fractures sutures may not be needed, but in comminuted fractures silver or stainless steel wire sutures are necessary to hold the fragments in apposition. Fractures of the ribs or costal cartilages frequently occur in association with fracture of the sternum, and this combination of fractures is apt to produce marked paradoxical motion of the anterior chest wall. Under such cir-

cumstances, open operation is indicated. The sternum and fractured cartilages or ribs are exposed by a midline incision. The skin, subcutaneous tissue, fascia, and pectoral muscles are freed and retracted from the midline. Fractured cartilages are approximated by simple on-end sutures of stainless steel wire. Fractured ribs are immobilized, as previously described, and the sternal fragments are brought into apposition by stainless steel wire sutures. If fracture of the sternum is accompanied by multiple, bilateral fractures of the costal cartilages, simple fixation of the carti-

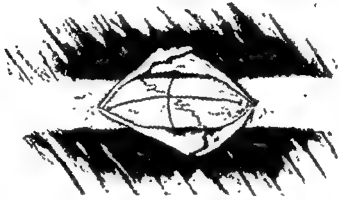

Fig. 344.—On-end wiring of oblique fractures accompanied by a circumferential wire.

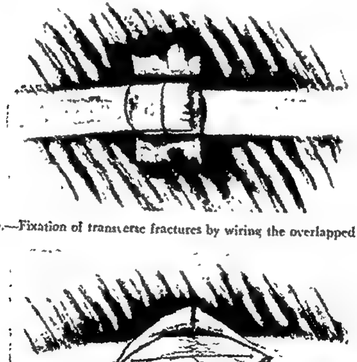

Fig 345.—Fixation of transverse fractures by wiring the overlapped fragments

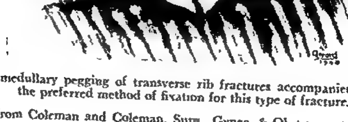

Fig 346.—Intramedullary pegging of transverse rib fractures accompanied by on-end wiring, the preferred method of fixation for this type of fracture.

(Figs. 344-346 from Coleman and Coleman, Surg., Gynec. & Obst.; courtesy The Franklin H. Martin Memorial Foundation.)

lages will not prevent paradoxical motion of the chest wall. In such cases the fractures of the sternum are fixed by wire sutures and the sternum is supported posteriorly by a stainless steel pin which is passed through a drill hole in a normal rib on one side to a corresponding rib on the other side. The pin is further anchored to the healthy ribs by circumferential steel wire sutures. Migration of the steel pins is avoided by this type of fixation and by removal of the pins in three or four weeks.

SOFT TISSUE WOUNDS OF THE THORACIC WALL; TRAUMATIC PNEUMOTHORAX; TRAUMATIC HEMOTHORAX

Incised and lacerated wounds of the chest wall do not give rise to any unusual problem unless they penetrate the thoracic cavity. Penetration of the thorax may result in hemorrhage from the heart or great vessels, the internal mammary or intercostal arteries, or from the larger pulmonary vessels. If the lung is penetrated, a bronchus may be injured, giving rise to tension or valvular pneumothorax. If the wound in the chest wall is of sufficient size, open pneumothorax results. If the opening is large, the patient will develop respiratory difficulty, and unless the opening is closed promptly a fatality may result. Such wounds may be temporarily closed by strips of flamed adhesive, by heavy rubber dam, or by a large petrolatum gauze pack. If no suitable material is available, temporary closure may be obtained by placing one hand above and the other below the incision and forcing the soft tissues together. Occasionally a lobe or even an entire lung may be extruded into the opening, effectively closing it. Should this occur, the lobe or lung should be left in place and covered by sterile saline sheets, until adequate facilities to repair the wound are available. The extruded lung is then carefully cleansed, replaced in the pleural cavity, and the wound is débrided. An intercostal catheter is placed for drainage and the lung is inflated before the last suture is tied.

Closed pneumothorax associated with wounds of the chest wall should be kept under observation but it rarely requires active treatment. Usually there is no serious disturbance of physiology and the air undergoes spontaneous absorption. On the other hand, prompt recognition of tension or valvular pneumothorax may be lifesaving, for this condition requires immediate treatment. Simple needle aspiration of the pleural cavity usually does not suffice but should be tried. It is often necessary to provide continuous drainage and this probably is best done by introducing a catheter into the pleural cavity by the trocar-cannula method. The catheter is connected with an underwater seal which permits continuous escape of air from the pleural cavity. If facilities for catheter drainage are not available, a large-bore blunt needle may be used and a flutter valve established by loosely tying a piece of thin rubber membrane about the hub of the needle. This permits the escape of air, but on inspiration the rubber is sucked against the opening in the needle, blocking it. It may be necessary to continue the decompression for a period of forty-eight to seventy-two hours.

Penetrating wounds of the chest wall practically always result in the collection of some blood in the pleural cavity, and hemothorax of sufficient size to produce symptoms is a frequent complication of such injuries. The primary treatment of this complication is early and, if necessary, repeated removal of blood by needle aspiration. If respirations, pulse, and blood pressure are fairly stable, aspiration should be carried out during the first twelve hours and should be re-

peated each day until the lung is completely expanded. Injuries to the internal mammary or intercostal arteries or to major branches of the pulmonary artery are usually serious, but are especially dangerous if they occur in connection with small penetrating wounds of the pleural cavity. Since the intercostal and internal mammary arteries lie near the pleura, the negative intrapleural pressure tends to cause continued bleeding into the pleural space. Often there is little or no external bleeding. The mortality from such injuries is high unless the source of hemorrhage is determined and the vessels are ligated. Rapid or continued intrapleural bleeding requires thoracotomy, even though there is shock. Access to injuries of the intercostal or internal mammary vessels may be obtained through one of the standard thoracotomy incisions. The approach may be anterior or posterior, depending upon the site of injury. Injured chest wall vessels are easily identified and ligated. If there is injury to a main lobar artery or vein, especially to the vein, lobectomy probably will be necessary.

The more important complications of traumatic hemothorax are infection and/or organization of the blood. Infection is especially apt to occur where there is extensive destruction of tissue or retained foreign bodies. Rapid intrapleural bleeding, especially in the presence of the extensive destruction of tissue, favors the formation of a massive clot which cannot be removed by needle aspiration. Early in clotted hemothorax the use of streptokinase will frequently lead to reexpansion of the lung. According to Sherry, Tillett, and Read, this material is prepared for intrapleural injection by adding a lyophilized ampule of streptokinase, containing 200,000 to 300,000 units, to 50 c.c. of normal saline. This solution is allowed to remain in the pleural cavity up to twenty-four hours, when all of the fluid should be removed by thoracentesis or by catheter. If complete liquefaction of the coagulum is not accomplished by the first injection, the injection may be repeated at forty-eight-hour intervals. The clot should be carefully localized by roentgenograms to determine the proper site for the introduction of the enzyme. Enzymatic decortication of the lung yields favorable results in the early stages of clotted hemothorax, but chronic organized hematoma usually will require open thoracotomy and surgical removal of the scar overlying the lung (Figs. 347 and 348). Blood clot usually assumes a dependent position within the pleural cavity, so a posterolateral incision is preferable, generally through the bed of the subperiosteally resected eighth or ninth rib. A cleavage plane is found between the scar and the pleura and is developed with ease if there has been no infection of the pleura or underlying lung. The scar is freed from the underlying pleura, parietal and visceral, by blunt dissection; pressure is applied to the scar, not to the thoracic wall and lung. The index finger or a gauze dissector is satisfactory for this purpose (*Fig. 349*). It is possible to remove extensive scar in this manner and without injury to the underlying lung. After the lung, diaphragm, and thoracic wall have been liberated, the underlying pleura may be practically normal in appearance. The pleural cavity is drained by intercostal tubes and the wound is closed in layers. The duration of the scar, even though it has been present for a number of years, should not be considered a contraindication to operation. The author has successfully removed such scar after as long as eighteen years. However, the most desirable time for decortication is six to eight weeks following the injury. The treatment of infected hemothorax is covered in the chapter on empyema. Infected organized hemothorax may be decorticated with relative safety.

Fig 347.

Fig 348.

Fig 347.—Residual chronic organized hemothorax of the left chest following adequate therapeutic trial with the enzymes streptokinase and streptodornase.

Fig. 348.—Seventeen days postoperatively. Reexpansion of left lung complete.

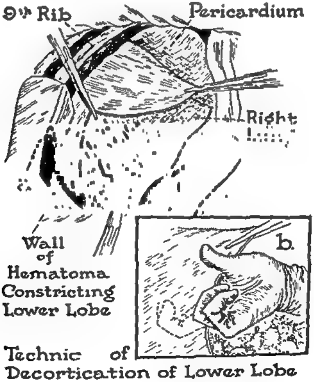

Fig 349.—Method of decortication of chronic organized hemothorax. (Coleman, Arch Surg, courtesy American Medical Association.)

The most difficult injuries of the chest wall to repair are shotgun wounds received at close range. They not infrequently involve all of the layers of the wall, and closure, after proper débridement, may be difficult. Under such circumstances it may be necessary to use pedicle muscle flaps or a portion of the diaphragm to close the opening.

INFECTIONS OF THE SOFT TISSUE, BONY AND CARTILAGINOUS STRUCTURES OF THE THORACIC WALL

Infections of the chest wall are usually treated in the same manner as are similar infections elsewhere, but certain infections present unusual problems. One of the most serious is the rapidly spreading cellulitis of the chest wall which usually results from contamination with anaerobic, gas-forming organisms. Such organisms may be introduced from the outside by puncture or by penetrating wounds, but more frequently they are carried into the tissues of the wall from the pleural cavity or lung by the aspiration of lung abscess or putrid empyema, as the positive pressure in an abscess during coughing or an associated tension pneumothorax helps force the infectious material out into the tissues.

The best treatment for such infections is the proper prophylaxis, but once they have developed they require wide incisions, extending beyond the margins of the area of involvement, and massive doses of suitable antibiotics.

Subpectoral abscesses develop rapidly and give rise to serious toxic symptoms, being unusual in these respects. They should be treated by wide incision along the axillary border of the pectoralis major muscle and by another perpendicular incision extending across the fibers of that muscle. The wound should be packed lightly with sterile gauze and allowed to fill in by granulations, for if it closes over too rapidly, sinuses are apt to develop which may later require even more extensive surgery.

Pyogenic osteomyelitis of the ribs and sternum is of relatively infrequent occurrence In the sternum it is probably best treated by conservative surgery; but in infection of the ribs complete subperiosteal resection of the infected segment of rib should be done. An incision is made over the infected rib and is carried through the periosteum beyond the septic area on each side. The rib is divided and the infected portion is completely removed. Special care should be taken to remove all of that portion of the rib which has been denuded of periosteum; otherwise, sequestra will form. The wound is lightly packed with gauze impregnated with petrolatum, and a sterile dressing is applied.

Tuberculous and typhoid infections usually develop at the costochondral junctions and involve the cartilages more extensively than the ribs. Moschowitz did much to improve the results obtained in the treatment of infections of the costal cartilages by insisting that all cartilage exposed to infection should be removed This is relatively easy in the upper five cartilages, for they are attached to the sternum independently of each other, but the next five are fused anteriorly, and infection in one of them may spread to all of the others. No standard incision is necessary or wise in these cases. Generally speaking, an incision starting near the xiphoid and extending downward and outward along the costal border beyond the tenth costochondral junction will suffice. The skin-fascia-muscle flap is dissected up sufficiently to expose the fused cartilages (the sixth to the tenth), which are then dissected out, care being taken to remove all cartilage and also to avoid injury

to the pleura. Draining sinuses should be carefully followed out and opened completely. Moschowitz also called attention to the frequent occurrence of sinuses along the sternal border which extend inward. He believed that they followed the course of the perforating branches of the internal mammary arteries and warned against injury to these vessels while opening up such sinuses. If there are no draining sinuses and no secondary infection, the wound should be closed loosely with interrupted sutures without drainage. If fluid accumulates beneath the flaps, it should be removed by careful needle aspiration. Following aspiration appropriate antibiotics are injected. These operations are best carried out under general anesthesia. Heliotherapy should be instituted soon after operation.

TUMORS OF THE CHEST WALL

Primary tumors of the chest wall may be divided into the superficial and deep varieties. The superficial benign tumors are treated by local excision, as they are elsewhere in the body, and since this presents no particular problem, it will not be discussed here.

The deeper tumors may originate in the soft tissues, or in the bony and cartilaginous framework of the chest wall. In any event, malignant tumors usually involve the bony framework by the time they come to operation. It may be stated, therefore, that malignant neoplasms originating in the deeper tissues of the chest wall all present similar surgical problems. All should be excised with a wide margin of normal tissue. The production of a pneumothorax prior to operation may help to determine whether or not the lung is involved. Complete removal of such tumors frequently requires excision of the entire thickness of the chest wall except the skin, and even this must sometimes be included. The more malignant tumors not infrequently invade the pleura and may involve underlying structures, such as the lung, diaphragm, or pericardium. Under such circumstances, it may be necessary to excise portions of these structures. Intratracheal anesthesia should, therefore, be used in practically all of these cases.

Adequate closure is often a difficult problem, requiring considerable ingenuity. Many structures have been used to close such openings, such as breast, pedicle muscle flaps, the diaphragm, and strips of fascia lata, with varying degrees of success. As a rule, when the opening is in the upper chest wall, satisfactory flaps may be obtained from the pectoralis major, the latissimus dorsi, or the trapezius muscles. Openings in the lower chest wall, especially lateral ones, usually can be closed by using the diaphragm (Fig. 350). When this structure is to be employed, the phrenic nerve should be identified as it courses downward on the lateral surface of the pericardium, and either pinched with a hemostat or divided with scissors. By this means the closure will be facilitated and there will be less danger of the sutures giving way before satisfactory healing has occurred. The lung itself has been sutured to the wound margins, but this is not as satisfactory as other structures and should not be used when more suitable material is available. In any event, before the final sutures are tied, the lungs should be well inflated so as to leave as little air as possible in the pleural cavity. An intercostal tube is introduced into the pleural cavity prior to suturing of the diaphragm to the chest wall. This tube assures deflation of the pleural cavity as well as the removal of serosanguineous fluid, it is re-

oxygen should be administered.

Although large defects of the chest wall may be repaired by sliding or pedicle of muscle or skin, the patient is left with a chest wall which bulges on straining ughing and moves in a paradoxical manner with respiration. A flap of fascia may be used, as advocated by Watson and James, and this diminishes the lity of the area. Bone or periosteum which will form bone should be employed ever possible since this alone gives a satisfactorily stable chest wall.

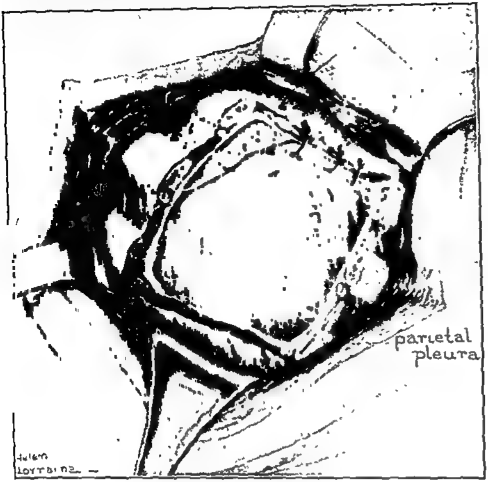

Fig. 350.—Method of using the diaphragm to close large defects in the thoracic wall. liaphragm has been relaxed by pinching of the phrenic nerve as it courses downward on ericardium.

Janes repairs the defect which results from the excision of a costal cartilage or nterior segment of a rib by splitting the next rib below and fixing the anterior of the upper segment in the position of the resected rib. The posterior end is ttached in its normal position. This preserves the symmetry as well as the sta- of the thoracic wall but, unfortunately, is not applicable to very large defects. Bone grafts from the tibia or ilium may be used to replace the sternum after ide resection, and Bisgard and Swenson suggest mortised rib grafts for the same ose. We have resected the eleventh rib with one-half of the periosteum at- ed and used it as a transplant to stabilize the closure of large defects of the

chest wall. The transplanted ribs are firmly anchored anteriorly to the sternum and posteriorly to a healthy rib. Metal plates are unsatisfactory for repair and stabilization of chest wall defects.

HERNIA OF THE LUNG

Hernia of the lung may occur through either the chest wall or the diaphragm, more frequently through the former. The repair of such hernias usually is relatively simple. An incision is made over the summit of the mass, and one or more ribs are divided if necessary for adequate exposure of the neck of the sac. The pleura forming the sac is dissected out but is not opened. It is inverted, and the overlying tissues, usually the intercostal muscles, are approximated over the site of the hernia. Lilienthal advocated anchoring a portion of a rib over this to give added strength.

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CHAPTER 30

THORACIC INCISIONS; FUNNEL CHEST OR PECTUS EXCAVATUM

I. A. Bigger

THORACIC INCISIONS

The majority of intrathoracic operations are performed through one of three types of incision. These incisions are usually described as posterolateral, anterolateral, and anterior midline or sternal splitting. The so-called posterolateral incision, the one most frequently employed, usually extends onto the anterior portion of the chest but the greater part of it does lie posteriorly and laterally. It follows the course of the ribs, being more oblique in asthenic individuals and more nearly horizontal in thick-chested men The incision is started posteriorly about three fingerbreadths from the spinous processes and is carried to, or a little beyond, the costochondral junction. It is made at that level best suited to the purpose for which it is to be used. For instance, when made for resection of a coarctation of the aorta, it should be so placed as to permit resection of the fourth or fifth rib, whereas when made for the exposure of a diaphragmatic hernia it should be placed over the eighth or ninth rib; when used for resection of the lung, it is placed about midway between these levels.

This incision has definite advantages, the most important being the extensive exposure it gives. It also has certain disadvantages such as the necessity for section of such heavy and important muscles as the trapezius, the rhomboids, and the latissimus dorsi, thereby causing greater blood loss, greater tissue injury, and prolonged operating time. Somewhat less muscle mass is encountered when the incision is over the lower chest wall. Except in very young individuals it is usually advisable to resect at least one rib When rib resection is done, it is best to divide the rib posteriorly near the spine and anteriorly at or medial to the costochondral junction. Both sections should be made with sharp rib shears to avoid leaving spicules which are apt to tear gloves or cause injury to the lung. In exposing the posterior portion of the rib, the sacrospinalis muscles are separated from the underlying ribs and are retracted toward the midline; section of these muscles is unnecessary. The majority of surgeons when using the posterolateral approach place the patient in the lateral position, and this increases the hazards of carbon dioxide retention and anoxia. Also, in suppurative lesions of the lung the lateral position increases the danger of spillage into the bronchi of the opposite lung The prone position, recommended by Overholt, is far better than the lateral position but requires special equipment.

The anterolateral incision is curved below the breast; in female patients it is placed in the submammary crease. Only in exceptional circumstances where time is of the greatest importance, as in pulmonary embolectomy, is the incision made at a higher level, directly across the pectoral muscles. As usually made, the incision is started at the sternal border at the level of the third costal cartilage and is carried downward and outward beneath the breast, then upward and outward into the axilla, ending near the posterior axillary line. In this way one avoids cutting *across the main mass of the major pectoral muscle in the anterior axillary fold.* As the incision is carried into the axilla, care should be exercised to avoid cutting the long thoracic nerve. The pectoral fascia and pectoral muscles are divided in line with the skin incision and these structures are retracted upward to expose the interspace chosen for entrance into the thorax. It is better to err on the side of a low entrance, for it is a simple matter to cut across one or more cartilages at the sternum, thus gaining exposure at a higher level. Division of cartilages below the level of entrance is less effective in gaining adequate exposure. After the pectoral and serratus muscles have been divided to the limit of the superficial incision, considerable added room is obtained by separating the ribs, at the level of entrance, well back to or even beyond the rib angles. This is most readily accomplished by passing a Semb rib margin elevator back along the upper border of the rib below the level of entrance into the thorax. This is not difficult if the groove in the elevator is pressed firmly against the rib margin as it is passed toward the spine. This maneuver allows for wider separation of the ribs than can otherwise be obtained.

The internal mammary vessels are dissected out, doubly ligated, and divided. If one or more cartilages are divided at the sternum, the corresponding intercostal vessels are ligated and divided. By this incision the thorax may be entered through the third, fourth, fifth, or even the sixth intercostal space, thus permitting access to the greater part of the corresponding pleural cavity and to the mediastinum. The exposure of the lower third of the chest cavity is less satisfactory than is that of the upper two-thirds. The exposure of the hilar structures is excellent. For pneumonectomy and upper and middle lobe lobectomy, the author prefers this approach. For lower lobe lobectomy the anterolateral incision is less satisfactory, especially when there are dense adhesions between the lung and diaphragm. At closure the divided cartilages are sutured to the sternum with 32 gauge (for adults) and 34 gauge (for children) stainless steel wire The ribs and cartilages are approximated by pericostal sutures of heavy catgut and the soft tissues are closed in layers with interrupted sutures.

The *anterior midline or sternal splitting incision* has fewer uses than either of the previously described incisions but is most useful for certain procedures, such as thymectomy, for the removal of some anterior mediastinal tumors, and especially in operations for aneurisms arising from the main branches of the aortic arch such as the innominate artery The anterior median incision is also useful in exposing the heart, especially for pericardiectomy The skin incision usually extends in the midline from the sternal notch to the xiphoid or beyond (Fig. 351). For high lesions a short transverse arm may be added at the level of the sternal notch. The entire sternum may be split in the midline, or it may be sectioned transversely at any level, then sectioned longitudinally below or above the level of transverse section as seems indicated. Especially designed shears and knives are available for section of

the sternum, but the ordinary Gigli saw serves the purpose as well as or better than any of them and is less expensive. Also with a Gigli saw the sternum can be sectioned at right angles to the surface or beveled as seems best. When the entire sternum has been sectioned longitudinally or a longitudinal section is combined with transverse section, a small rib-spreading retractor is inserted and an excellent exposure is obtained. At closure the sternum may be drilled and approximated by 30 or 32 gauge stainless steel wire sutures, or a satisfactory closure may be obtained by carefully suturing the anterior periosteum of the sternum with 34 gauge steel wire.

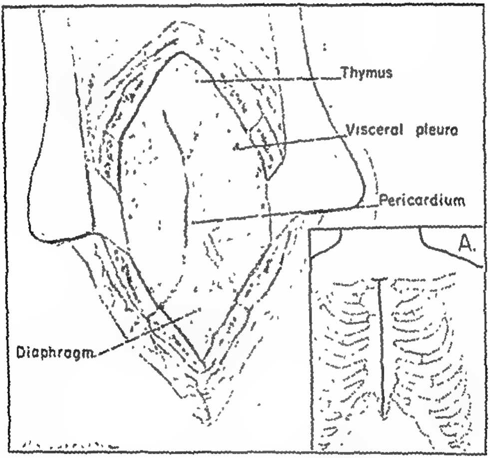

Fig 351.—Complete median sternotomy The longitudinal section may be shortened and the sternum divided transversely at the desired level.

FUNNEL CHEST OR PECTUS EXCAVATUM

Of the developmental deformities of the chest wall, pectus excavatum or funnel chest is the most common and the most important. Brown directed attention to the importance of shortening of the central tendon of the diaphragm as the cause of the deformity, and Lester also has emphasized this factor. Both Brown and Lester have stressed the importance of detaching the xiphoid from the sternum and dividing the substernal ligament, thereby releasing the sternal attachment to the central portion of the diaphragm.

The majority of surgeons agree that the deformed cartilages should be resected so that the sternum may be brought forward. but there is considerable difference of opinion as to the best method of maintaining the sternum in the anterior position. Ochsner prefers making a plaster shell with sufficient space anteriorly to permit the

use of elastic bands to hold the sternum in the desired position. Lester uses a modified Brown ladder which rests on the anterior wall and to which wires are attached for support of the sternum. Dailey, Dorner, and Bosher have used a section of the ninth rib, which is placed posterior to the sternum and is attached to the rib ends on each side so that it acts as a truss or support for the sternum. Brown, who originally devised the ladder for external support of the sternum, states that he no longer uses any support for the sternum. There are obviously a number of relatively satisfactory methods by which the sternum may be maintained in a more normal position

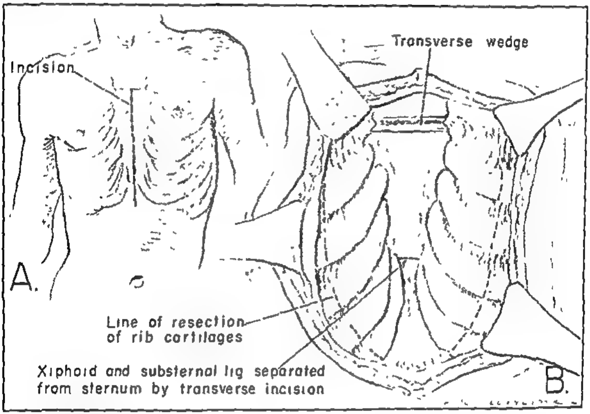

FIG 352.—Operation for correction of pectus excavatum. *A,* The deformity and line of incision. *B,* The sternum has been divided. Dotted lines show division of costal cartilage.

The indications for operation are physical and psychological; both are important. There is no doubt that patients with pronounced funnel chest usually have evidence of interference with the circulation which is at least partially due to cardiac displacement and compression, and some of these individuals are seriously handicapped The breathing capacity also may be considerably reduced, but the effects on respiration are far less important than the effects on the circulation. It is now evident that when operation is performed early the immediate results are better, but patients operated upon early in childhood have not yet been followed sufficiently long to be certain of the final results On the other hand, it is certain that those patients operated on late in life have functional and structural changes which cannot be altogether corrected.

Older children and adults are best operated upon under intratracheal anesthesia, but in very young children a tightly fitting mask is to be preferred. The author has used the following procedure and has found it satisfactory (Fig 352). An in-

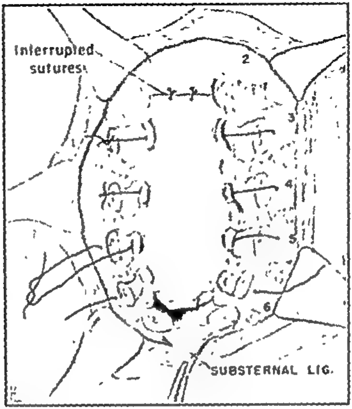

Fig. 353.—Drill holes have been made in the ribs and the sutures have been passed under the sternum, holding the sternum in position. (Kangaroo tendon is used for this purpose in children.)

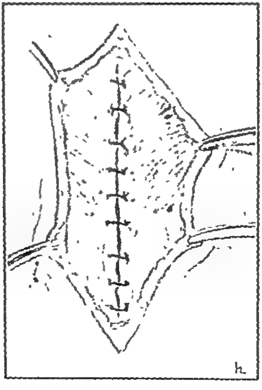

Fig 354.—Closure of presternal fascia.

ion is made in the midline anteriorly from the angle of the sternum to the mid-igastrium. The superficial structures including the fascia and pectoral muscles are)arated from the sternum and from the costal cartilages and are retracted later-y. The xiphoid is separated from the sternum by a transverse incision, which o divides the substernal ligament, an upward extension of the linea alba. The ıse tissue is separated from the posterior surface of the sternum and the pleura is shed back on each side to the costochondral junction or a little beyond. The steriorly angulated cartilages are then resected subperichondrially. A small trans-:se wedge is removed from the anterior plate of the sternum just below the angle; : sternum is bent forward and fixed in the anterior position by a few interrupted ures of fine (32 or 34 gauge) stainless steel wire. Drill holes are made near : ends of two or more ribs on each side, usually the third or fourth and the fifth sixth, and heavy sutures are passed posterior to the sternum, then through the ll holes in corresponding ribs, and are tied with sufficient tension to hold the ster-m in a position of slight overcorrection (Fig. 353). In the past, No. 30 stainless el wire was used for this purpose in adults and No. 32 stainless steel wire in chil-:n. Recently heavy kangaroo tendon has been used with satisfactory results ere are possible advantages in the use of absorbable material, especially in chil-:n. The fascia, subcutaneous tissue, and skin are approximated in layers with errupted sutures (Fig. 354). Not infrequently the pleura is injured and air en-s one or both pleural spaces, so at the completion of the operation it should determined whether or not this has occurred. If air is present in either pleural ıce, it should be removed by aspiration.

External support apparently is unnecessary. Flexible internal supports such wire, or, even better, heavy absorbable material such as kangaroo tendon or ·omic catgut probably are preferable to a rigid support such as a section of rib.

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CHAPTER 31

OPERATIONS FOR LESIONS INVOLVING THE PLEURA AND PLEURAL SPACE

RECURRENT AND CHRONIC PNEUMOTHORAX; ACUTE EMPYEMA; CHRONIC EMPYEMA

I. A. Bigger

PNEUMOTHORAX

One of the common conditions involving the pleural cavities which surgeons are called upon to treat is pneumothorax, either spontaneous or accidental. As has been pointed out, pneumothorax may be open, closed, or of the tension or valvular type. Both closed and valvular pneumothoraces are especially apt to follow injury to the chest wall by blunt force, with or without associated rib fractures. Closed *pneumothorax results from the passage of air into the pleural cavity, usually through* a superficial rent in the lung. This allows the lung to collapse and this tends to approximate the margins of the wound, allowing it to become sealed by fibrin. By the time the lung expands as a result of the absorption of air, the wound is so firmly healed that no more air escapes. It is better, therefore, not to aspirate in either spontaneous or accidental pneumothorax unless there is a special reason for doing so. When aspiration is necessary, it should be done under careful aseptic precautions, preferably by the use of an ordinary therapeutic pneumothorax apparatus, connected so that air may be withdrawn by the flow of water from one bottle to another. In this way the intrapleural pressure may be determined at frequent intervals and the withdrawal of air is discontinued before the intrapleural pressure *becomes sufficiently low as to cause further leakage.*

Valvular pneumothorax is the result of rupture of the lung with involvement of a bronchus, either from trauma or from the spontaneous rupture of a superficial pulmonary cyst or emphysematous bleb In either case, air may continue to escape into the pleural cavity until a positive intrapleural pressure develops. Intrapleural pressures greater than atmospheric pressure cause respiratory disturbance unless the mediastinum is fixed by adhesions or by inflammatory thickening. The continued escape of air apparently is due to the fact that the bronchi enlarge during inspiration and decrease in size during expiration, so that, when the lung is collapsed, the opening in the bronchial wall acts as a valve, allowing air to pass through into the pleural cavity during each respiration, and a portion is trapped there.

The *treatment* of valvular or tension pneumothorax depends upon whether or not the escape of air is automatically controlled before dangerous pressure develops.

If the intrapleural pressure rises only a little above atmospheric pressure and causes only mild symtoms, conservative treatment is probably best, but it is essential that careful observations be made on the pulse rate and volume, blood pressure, respiratory rate and depth, and whether or not cyanosis develops. Should there be evidence of marked increase in pressure, aspiration should be done in the manner described for closed pneumothorax; but if the positive pressure continues to recur, especially if it recurs rapidly, an intercostal tube should be inserted and connected with water-seal drainage.

Spontaneous pneumothorax may persist or continue to recur. In either case it is apt to be associated with pulmonary cysts or emphysematous blebs or bullae.

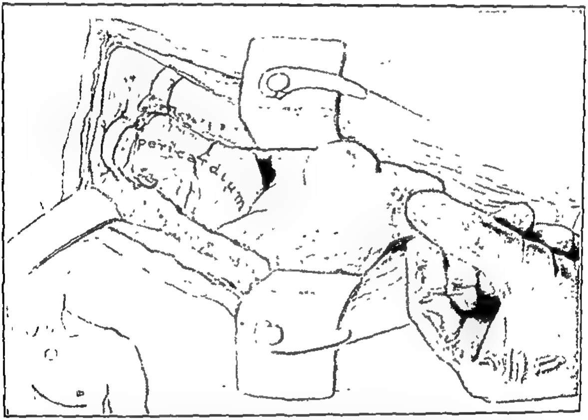

Fig 355—Appearance of subpleural bleb. Anterior incision for the exposure of a subpleural bleb which was permitting air to escape into the pleural cavity, producing chronic pneumothorax The bleb was excised along with a small amount of lung tissue and the lung margins were approximated with interrupted sutures.

Continued recurrence or persistance of pneumothorax generally requires surgical intervention, the character of the surgery depending upon the underlying cause. When the pneumothorax is due to rupture of a pulmonary cyst, the cyst should be removed, but emphysematous blebs and bullae are not amenable to such direct attack. Brock applies a 20 per cent solution of silver nitrate to the pleura, thereby causing it to thicken and adhere In the majority of cases, Brock applies the silver nitrate through the thoracoscope Meade and Blades do a thoracotomy, excise the blebs and suture the lung, closing obvious sites of leakage by suture. (Fig. 355.) They then apply an irritating substance, usually talc, to the pleura. Although Brock has obtained excellent results by applying the pleural irritant through the thoracoscope, thoracotomy seems advisable.

ACUTE EMPYEMA

Acute empyema may be caused by any of the ordinary pyogenic organisms, but the majority of cases are due to pneumococci or streptococci. Pneumococcic empyema usually follows lobar pneumonia or, stated differently, the infection of the pleura usually develops late, frequently not until the pneumonia has begun to resolve. Also lobar pneumonia often involves only one lobe; rarely both lungs. Since the empyema develops on the side of the pulmonary infection, the opposite lung may be capable of functioning in a fairly normal manner, and the patient's vital capacity is not greatly diminished. Streptococcic empyema, on the other hand, usually accompanies bronchopneumonia and not infrequently develops almost simultaneously with the pulmonary infection. Also, bronchopneumonia frequently involves both lungs, and bilateral empyema is not especially rare. Streptococcic empyema, therefore, usually causes a much greater reduction in vital capacity than pneumococcic empyema These considerations are important in the treatment of patients with acute empyema and indicate that there is no special need for haste in evacuating fluid in most cases of pneumococcic empyema; however, in certain cases of streptococcic empyema, early evacuation of the fluid is necessary, especially if it accumulates rapidly or is bilateral. There is no urgency in establishing continuous drainage in empyema, but aspiration should be done at frequent intervals followed by the injection of appropriate antibiotics.

The use of antibiotics has brought about a marked reduction in the incidence of pleural empyema. Also, the combined systemic and local use of the antibiotics has made surgical drainage unnecessary in a considerable percentage of cases. This is particularly true when the empyema is recognized early and is treated vigorously. This plan of treatment has definite advantages over surgical drainage but carries with it a danger which must be recognized and avoided. This danger is that of persistence in using this type of treatment in spite of the continued formation of purulent fluid. Such persistence may be due in part to the physician's enthusiasm and possibly also to a misunderstanding of the significance of the continued appearance of purulent fluid. The fact that such fluid is apt to give negative bacteriologic findings is misleading, and even though such fluid consistently gives negative cultures it should be recognized as pus and so treated. Adequate, continuous drainage should be established while the walls of the empyema cavity are still pliable, otherwise one may be faced with the problem of treating a chronic empyema. Read, working with Tillett, has shown that streptokinase-streptodornase used in conjunction with surgical drainage gives excellent results in such cases.

When established sufficiently early, intercostal, underwater drainage is entirely adequate and in most ways preferable to rib resection with open drainage.

Putrid empyema, usually secondary to ruptured lung abscess, is an altogether different problem from the ordinary postpneumonic empyema. There is often an associated tension pneumothorax which is in itself an indication for prompt drainage, also, the organisms usually are virulent anaerobes, little if at all affected by antibiotics. Aspiration is contraindicated unless it is to be followed immediately by continuous drainage This is true for several reasons: the organisms implanted in the wall by the aspirating needle are virulent anaerobes, and in addition the air

and pus are under pressure and may continue to be forced out into the needle tract, thus leading to widespread infection. Putrid empyema should therefore be considered a surgical emergency.

Aspiration of Pleural Cavity

Local anesthesia may be used in all operations for acute empyema and, when properly administered, it is entirely satisfactory even in relatively young children. Aspiration may be done either for diagnosis or treatment, but the location of the pus should first be carefully determined by physical examination and by roentgenography. Roentgenograms should always be made in both the anteroposterior and the lateral planes, as either one alone may be misleading. After the pus has been accurately localized, a local anesthetic (1 per cent procaine solution in adults and weaker solutions in children) is injected in an interspace over the lower portion of the cavity. A skin wheal is formed, using an ordinary hypodermic needle A 22 gauge, 5 cm needle is then used to inject the procaine solution at varying levels, with especial care to deposit some just outside the pleura. A No. 18 or 19 caliber needle attached to an ordinary 10 or 20 c.c. Luer syringe is carefully inserted at the upper border of a rib and is advanced cautiously so as to avoid injury to the intercostal vessels. The pleura will be recognized by its density. As soon as the needle passes through the pleura, the plunger is withdrawn. If pus is not obtained, it is better to try another interspace, usually the one above. When pus is found a sufficient amount is immediately removed for smears and cultures. If it is decided to evacuate the greater part of the pus, a 50 c.c. syringe and a three-way stopcock are employed, so as to save time and, more importantly, prevent the entrance of a large amount of air. As much fluid is then removed as seems wise under the circumstances. If the patient complains of dyspnea, or tightness in the chest, or begins to cough, aspiration should be discontinued at once. Seven or eight hundred cubic centimeters are usually a safe amount to remove from otherwise healthy adults

Intercostal Drainage

This operation is easily performed under local anesthesia and in very ill patients is readily done in the patient's room. After adequate local infiltration with the anesthetic solution, a small incision is made over the upper border of the rib immediately below the interspace through which the drainage tube is to be inserted. A cannula sufficiently large to carry a No. 22 or 24 (French) catheter should be used in adults, and a somewhat smaller one in children. The trocar is inserted through the incision in the skin, the skin is displaced slightly upward, and the trocar and cannula are carefully passed by a to-and-fro rotating motion through the tissues of the chest wall just above the costal margin The hand propelling the trocar should be carefully braced as the instrument contacts the pleura, to avoid forcing the trocar too far in as the resistance suddenly disappears As soon as the instrument has passed through the pleura, the trocar is withdrawn a short distance, and a catheter, marked to indicate the desired depth, is inserted into the side arm of the cannula; the trocar is then withdrawn the full length of the cannula, and the catheter is passed through the cannula into the pleural cavity. After the catheter has been placed well within the cavity, the cannula is removed and the catheter is left in place The depth of the catheter is then adjusted, using the mark as a guide

Silk sutures are inserted into the skin on each side of the catheter and tied. Each suture is then tied around the catheter two or three times to fix it in place. Some of the pus is withdrawn and a clamp is placed on the catheter until it is connected for closed drainage. Ordinary water-seal drainage usually is very satisfactory. This type of drainage may be used safely and satisfactorily in almost any type of acute empyema except that resulting from ruptured lung abscess.

Rib Resection With Drainage

One per cent procaine solution containing one drop of epinephrine to 30 c.c. is injected intradermally over the rib to be resected for a distance of 7 to 8 cm. A 22 gauge, 5 cm. needle is then used to infiltrate the deeper tissues with procaine solution. Infiltration of the muscles overlying the rib and in the adjacent intercostal spaces is begun posteriorly, then extended anteriorly, along the proposed line of incision. An incision 6 to 7 cm. in length is made down to the periosteum.

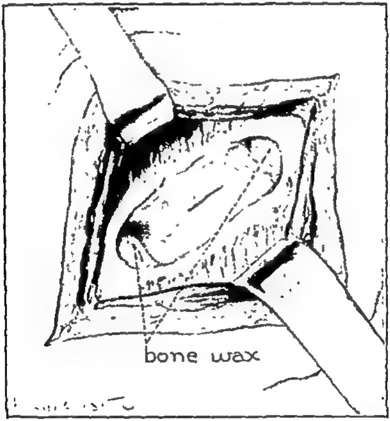

Fig 356.—Method for closed drainage of the pleural cavity following rib resection.

Procaine solution is now injected beneath the periosteum and the external periosteum is incised longitudinally for 5 or 6 cm., and then cross incisions are made at each end of the longitudinal incision The periosteum is carefully stripped from the surface of the rib, then from its lower and upper margins The intercostal structures and periosteum are separated from the upper border of the rib from behind forward and from the lower border from before backward. A Doyen elevator is used to separate the internal periosteum from the rib. It is important that all of the rib which has been denuded of periosteum be resected, otherwise that portion left uncovered may sequestrate and lead to prolonged drainage. Before the pleura is opened, the ends of the rib may be treated with bone wax to help prevent infec-

tion. If closed drainage is to be used, a small incision is now made through the internal periosteum and pleura (Fig. 356) and a large soft rubber tube is forced through this opening so that the margins of these structures fit the tube snugly (Fig. 357). A chromic catgut suture is placed through the internal periosteum and pleura on each side of the tube and tied, to prevent enlargement of the opening. The ends of these sutures are tied around the tube to hold it in place. It is important that the tube should not be inserted too far within the pleural cavity and also that there be an opening in close proximity to the pleura. A part of the pus is evacuated and the tube is clamped until connected for closed drainage. The intercostal muscles, fascia, and skin are approximated with interrupted sutures so that they fit snugly around the tube.

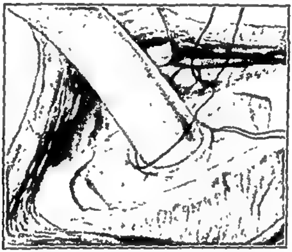

Fig. 357.—A large soft rubber tube is forced through the pleural incision and each end of the incision is reinforced by sutures which are inserted through the internal periosteum and pleura Both sutures are tied, and then tied around the tube to fix it in place.

Drainage for empyema caused by virulent anaerobic organisms is done in a manner similar to that just described except that the tissues of the chest wall other than the internal periosteum and the pleura are not closed around the tube The incision in the internal periosteum and pleura is carefully approximated around the tube, which is fastened in place with the long ends of these sutures By leaving the superficial tissues open, the danger of extensive cellulitis is obviated. This type of closed drainage will usually not remain airtight for more than six or seven days, but by the end of that time the entrance of air into the pleural cavity is of no especial importance When the muscles, fascia, and skin are approximated closely around the tube, as is done in other types of empyema, closed drainage can be continued almost indefinitely As a general rule, however, at the end of ten days or so, the tube is cut off and open drainage is instituted so that the patient may be allowed to go about freely.

Operations for Interlobar and Mediastinal Empyema

Either of these conditions may present special problems at the time of operation because occasionally the pus is completely enclosed between the lobes of the lung or between the lung and mediastinum and therefore does not come in contact with the lateral chest wall at any point. When this condition is found, the operation may be divided into two stages: At the first stage a rib is resected, for inter-

lobar empyema either the fifth or sixth rib in the midaxillary line, and for mediastinal empyema one of the cartilages and a short anterior segment of rib. The resection is done subperiosteally: the internal periosteum is incised and stripped from the pleura with especial care until it can be determined whether the two layers of pleura are adherent. If the lung can be seen moving underneath the parietal pleura, the wound is packed with gauze, which is left in place for several days. At the second stage of the operation the parietal pleura is incised, and in interlobar empyema the lobes are separated by finger dissection and the empyema cavity is entered and drained. In mediastinal empyema the lung is separated from the mediastinal pleura and the empyema cavity is drained. Under such circumstances open drainage is satisfactory.

Whenever an infected intrathoracic cavity, presumably an empyema cavity, fails to heal under the usual methods of treatment, the possibility of its being a large infected pulmonary cyst should be considered and sections should be obtained from the walls of the cavity for microscopic study. If there is an epithelial lining to the cavity, this lining must be destroyed or removed. Maier and Haight made an important contribution when they called attention to this problem several years ago.

CHRONIC EMPYEMA

Empyema is usually termed chronic when it has persisted for more than three months. This is unfortunate, as the length of time necessary for an empyema cavity to become obliterated depends upon many factors, such as the size of the cavity, the adequacy of drainage, the presence or absence of bronchial fistulas, and the general condition of the patient. Also of importance are the location of the cavity and its relation to the walls of the thorax. If both the upper and the lower limits of an empyema cavity are formed by adhesions between the lung and the lateral thoracic wall, healing will naturally be more rapid than if the upper attachment is to the lateral thoracic wall and the lower attachment to the medial portion of the diaphragm. Since there are so many factors involved, it would seem more logical not to speak of an empyema as chronic after a certain time has elapsed, but to reserve the term for those cases in which the cavity is no longer progressively decreasing in size. In other words, as long as an empyema cavity continues to diminish in size, the condition should be described as acute or subacute. The terminology is important in relation to treatment, for one usually thinks of radical surgical measures when an empyema is described as chronic, whereas extensive procedures, especially those involving chest collapse, are not indicated so long as the cavity is being obliterated by other means.

The most important factor in the development of chronic empyema is inadequate or improper drainage. We should consider drainage inadequate or improper when it is instituted too late or when open drainage is established too early. We should also consider drainage inadequate when the tube is too small or is improperly placed, as when it projects too far into the thorax and does not have fenestra near the thoracic wall Drainage is also inadequate when there are multiple pockets, some of which are not drained. Accessory or secondary pockets should be suspected when a patient does not show prompt improvement following the drainage of an empyema cavity; and unless there is some other obvious cause for the failure to

improve, roentgenograms should be made in various positions in an effort to demonstrate accessory cavities. If accessory or subcavities are suspected or proved, streptokinase-streptodornase should be used to convert the infected area into one space. Should this fail, the cavities should be drained surgically through the original opening or through new incisions. Although drainage through the old incision sounds simpler, it frequently is not as safe as making a new entrance. Drainage is of course inadequate when the tube is removed before the cavity is completely obliterated. This error is not made as frequently as it formerly was, but it still occurs too often. The size of the cavity may be determined so easily by measuring the amount of fluid it will hold that there is little justification for premature removal of the tube.

Fig. 358.—Incision for decortication of the lung

Ideal drainage may be described as that which is instituted as soon as the pus becomes walled off by adhesions, through a sufficiently large tube placed in a dependent portion of the cavity and left in until the cavity is completely obliterated. If these principles were universally adopted, nontuberculous chronic empyema would become rare indeed. As a matter of fact, the work of Graham, Lilienthal, and others led to a better understanding of the principles involved in the treatment of empyema. The antibiotics have also had an important effect by reducing the incidence of all empyemas

When an empyema cavity no longer decreases in size, the first procedure is to determine whether there is adequate drainage. If the drainage is not satisfactory, adequate drainage should be established, and this usually should be followed by

irrigation with normal saline solution until the presence or absence of pleurobronchial fistulas is determined. If there are no fistulas, one of the enzymatic agents should be tried.

If these substances fail to bring about progressive lung expansion, it becomes evident that complete obliteration of the cavity cannot be achieved without further surgery. The type of operation should not be decided upon until the factors responsible for the failure of conservative treatment and the chances of success offered by the various operations used in the treatment of chronic empyema have been given due consideration.

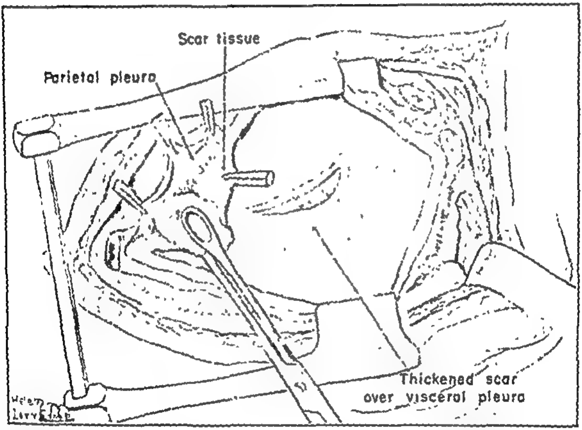

Fig. 359—Decortication of the lung. The scar is being removed from both parietal and visceral pleurae.

Definite indications for these various operations are difficult to describe, but it is clear that those procedures designed to conserve lung volume and breathing capacity should be considered first. The various procedures designed for this purpose all attempt to obliterate the empyema cavity in so far as possible by releasing the lung from its constricting scar. The most recent efforts in this direction were initiated by the work of Tillett and his associates with certain enzymatic substances, notably streptokinase-streptodornase. While these substances are apparently of greater value in the prevention of chronic empyema, they also have been shown to have value in its treatment. However, in cases allowed to develop true scar, which binds the lung in a collapsed state, surgical excision of the scar usually will be necessary. Before this is done a pleural biopsy is advisable, for tuberculosis is sometimes found when it is not suspected.

The exact technic of scar removal varies, of course, with the size and location of the empyema cavity. Exposure of the cavity is usually best obtained by a long incision in line with the ribs and centered over the cavity (Fig. 358). One rib is usually resected throughout the extent of the incision and adjacent ribs are divided if this is necessary to secure an adequate exposure. Not infrequently several ribs have to be sectioned, because the thickened chest wall pleura makes wide separation of the ribs difficult. When the entire cavity can be satisfactorily visualized, it is carefully inspected for sinus tracts which may lead into small abscesses or sub-pockets. Suspicious areas should be probed, and if sinuses are found, they should be opened widely.

Fig. 360.—Line of incision through heavy muscles of chest wall in Carter's operation for subacute or chronic empyema

If the parietal pleura is to be removed, it is somewhat easier and more satisfactory to free this up first. A satisfactory line of cleavage usually can be developed along the line of incision, and when the proper cleavage plane has been entered the organized exudate usually will peel away without great difficulty until the angle of junction between the parietal and visceral layers is reached. (Fig. 359.) It is well to remember you are not attempting to excise the pleura, only the exudate deposited upon the pleura. Removal of the chest wall pleura results in excessive bleeding, and

removal of the visceral pleura results in unnecessary lung injury. If the scar is very firmly fixed to the underlying lung, it indicates there was and probably still is an inflammatory area in the underlying lung. Such areas of densely adherent scar are often best left, removing the less adherent portion. When the angles or areas of junction of visceral and parietal pleura are separated first from one side, then from the other, the entire mass of scar usually can be removed without undue difficulty or risk. Should adherent areas of scar be found over the great vessels, it may be

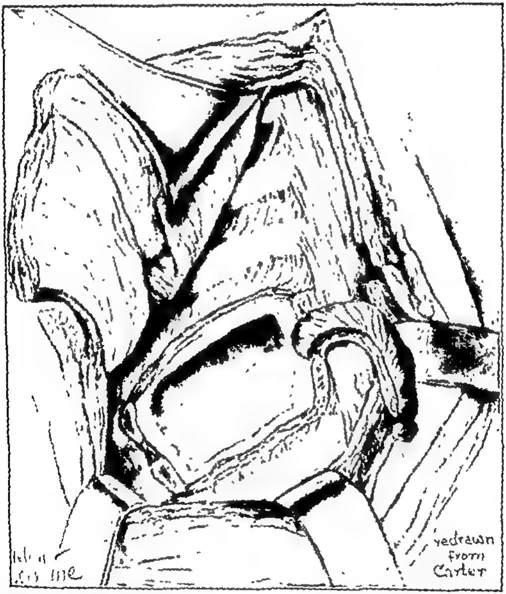

Fig. 361.—Two ribs have been resected and the thickened parietal pleura excised over the dependent portion of the empyema cavity. Note that the intercostal muscles have been preserved.

safer to leave those areas. Under some circumstances one may justifiably remove the thickened scar over the visceral pleura, leaving that over the parietal pleura. It should be realized, however, that the result will be less satisfactory, for chest wall mobility will return less rapidly and less completely.

When extirpation of the scar has been completed, a tube should be placed in the old drainage tract or in a new, more dependent area, and the chest wall wound should be closed with heavy pericostal sutures for approximation and fixation of

the divided ribs. The fascia and muscles are approximated with interrupted sutures. Blood loss may be considerable and should be replaced during the operation. Underwater drainage may be used for the first twenty-four to forty-eight hours, but continuous suction is advisable thereafter so that lung expansion will be maintained.

In making the decision as to whether or not surgical decortication is to be done, the duration of the empyema, even though it may have been present for a year or more, should not deter one. The extent and character of the pulmonary and pleural infection are of greater importance in relation to extirpation of the scar and ability of the lung to expand than is the time factor.

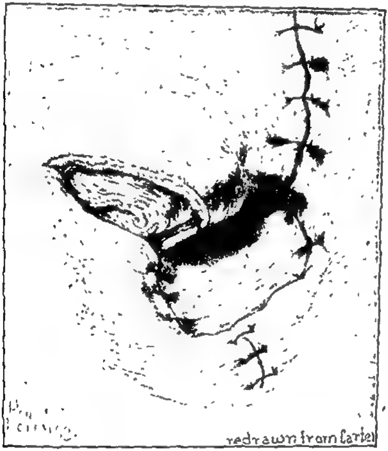

Fig. 362.—Method of closure in Carter's operation for empyema, showing the mass of heavy muscles rolled up beneath the upper skin flap.

Tuberculosis of the pleura is not necessarily a contraindication to decortication, but removal of the scar is almost certain to be more difficult and the results are apt to be less satisfactory. Active underlying pulmonary tuberculosis should be considered a contraindication unless the disease is confined to one lobe. If the disease is confined to one lobe, the scar may be removed and the diseased lobe excised or, in case of an involved upper lobe, collapsed by thoracoplasty. Pleurobronchial fistula need not deter one from excising the scar, for the fistulous tract can be dissected down to its junction with the bronchus, then excised, and the bronchus closed by suture. Should the bronchial fistula connect with a bronchiectatic abscess, excision of the involved pulmonary segment is necessary.

If, for any reason, decortication is contraindicated, or when there is incomplete closure of the cavity following decortication, measures must be taken to com-

plete the cavity closure. Such measures as localized extrapleural rib resection or rib resection in combination with muscle transplants or temporary exteriorization of the cavity, to be followed if necessary by muscle implants, are to be considered. The procedures described by Carter are useful under such circumstances.

Carter contends that tube drainage is necessarily somewhat unsatisfactory and recommends the resection of long segments (10 to 15 cm.) of at least two ribs over the most dependent portion of the cavity. This is done through a curved incision which more or less closely follows the line of the inferior border of the cavity. A vertical incision is extended downward for a short distance from the lowest portion of the curve and the skin flaps are then dissected up to expose a wide area of muscle.

Fig 363—The use of muscle flaps for obliteration of a residual empyema cavity and implantation of strips of muscle into pleurobronchial fistulas (Carter).

The heavy muscles of the chest wall are divided at a considerably lower level than the curved skin incision (Fig. 360). After the large muscle flap has been elevated, it is retracted out of the field while the ribs are resected. The intercostal muscles are preserved, but the thickened parietal pleura is excised from the area beneath the resected ribs (Fig. 361). The large muscle flap and the intercostal bundles are

tucked or rolled up beneath the skin flap for future use and the lower edge of the upper skin flap is sutured to the upper edge of the pleural opening. The short vertical incision is approximated and the lower skin flap is sutured to the pleura (Fig. 362). This procedure not only establishes good drainage but also exposes the cavity so that it can be lightly packed with gauze saturated with Dakin's solution or one of the antibiotics. This appears to be an entirely rational procedure and in properly selected cases should give excellent results.

The second stage of Carter's operation is a combination of the use of muscle flaps to close cavities and the use of the intercostal muscles or segments of other muscles as implants to close pleurobronchial fistulas, as recommended by Wangensteen, Pool and Garlock and others (Fig. 363). While there are necessarily innumerable variations of such an operation, depending upon the size, contour, and location of the cavity, the presence or absence of bronchial fistulas, etc., the same general principles are applied to all of them. The ribs are resected well beyond the limits of the cavity in all directions, the parietal pleura is excised, and muscle flaps are transplanted to fill in the portions of the cavity which cannot well be obliterated by relaxation of the chest wall. The trapezius, latissimus dorsi, sacrospinalis, and serratus muscles may be used. Persistent bronchial fistulas are closed by small muscle implants from the intercostals or other muscles (*Fig* 363). Finally, if the skin flaps are not sufficiently large to cover all raw surfaces, skin grafts may be used to close the defects.

Before such an operation is undertaken, the condition of the patient should be improved as much as possible by the establishment of adequate drainage, by a high caloric diet, and, if necessary, by multiple blood transfusions. The walls of the cavity should be as nearly sterile as possible.

The number of stages necessary to complete such a procedure will depend upon the patient's general condition as well as upon the size and location of the cavity. Small residual cavities may be safely obliterated at one operation, whereas large cavities may require several stages As so strongly emphasized by Keller it is advisable to proceed carefully, discontinuing the operation if there is a fall in blood pressure which fails to show a prompt and satisfactory response to the administration of blood.

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CHAPTER 32

THE LUNGS AND BRONCHI

I. A. BIGGER

Operations upon the lungs and bronchi may be indicated for the repair of wounds or for removal of foreign bodies; for drainage in lung suppuration; and for excision of diseased tissue, which may necessitate the removal of a segment or segments of one or more lobes, a whole lobe, or an entire lung. In addition to procedures which attack the lung directly, a number of operations have been devised which produce rest, relaxation, collapse, and even compression of the diseased pulmonary tissue. These operations are described collectively under the term collapse therapy and are most frequently indicated in pulmonary tuberculosis.

REPAIR OF WOUNDS OF THE LUNG

Injuries to the lung are often treated conservatively, but operation is indicated in severe lacerations, especially those involving bronchi, and in injuries in which there are retained foreign bodies. Severe pulmonary lacerations, associated with open or tension pneumothorax or persistent bleeding should be treated by thoracotomy, débridement, and repair. The original wound in the chest wall may be sufficiently extensive to permit adequate exposure of the lung, but as a rule it is necessary to increase the length of the incision along an intercostal space. A rib spreader is then inserted, the ribs are widely separated, and the injured lung is drawn up into the wound. In injury to large vessels, hemorrhage may be temporarily controlled by grasping the lobe or lung proximal to the point of injury or by applying a pulmonary hilar tourniquet or even a rubber-shod clamp. That portion of the lung tissue which is obviously deprived of blood supply is excised and the margins of the wound are approximated with interrupted sutures. It is usually impossible to ligate each injured pulmonary vessel, but the larger vessels should be closed by suture ligatures. Bleeding from small vessels is controlled by deep sutures. Severed small bronchi are also closed by sutures. When larger bronchi are severed, the lung distally may require excision, for the corresponding branches of the pulmonary artery and vein are also apt to be injured. The wound in the chest wall is débrided and approximated by heavy pericostal sutures and interrupted sutures for the muscles, fascia, and skin. An intercostal catheter is used for underwater drainage. Wounds of the lung in association with extensive mobilization of the chest wall by multiple rib fractures are usually repaired at the time of fixation of the ribs.

REMOVAL OF FOREIGN BODIES

There is no general rule applicable to the treatment of all foreign bodies in the lung. Some surgeons are inclined to remove every demonstrable foreign body, whereas others treat such cases conservatively unless there is a special indication for removal. We know that many small metallic foreign bodies remain in the lungs for long periods without producing any signs or symptoms. The decision in each individual case will have to be made on the basis of a number of factors, such as the size, shape, and location of the body; whether it is organic or inorganic; and the age and general condition of the patient. The probable degree of contamination should also play a part in this decision. It is advisable to remove organic material such as fragments of ribs, etc., and the removal of pieces of woolen clothing is imperative. Small metallic bodies, such as shot and small bullets, usually are not removed. Larger bullets, especially when irregular and distorted, generally should be removed.

If it seems advisable to remove a foreign body from the lung, the approach should depend upon its location (especially in relation to the hilum of the lung), the length of time it has been in the lung, and the presence or absence of infection. The first problem is accurate localization. This may be accomplished by roentgenography and fluoroscopy in radiopaque bodies, and even in nonopaque bodies roentgenograms are helpful, as the presence of a foreign body in the lung produces a reaction in the adjacent lung tissue. If the decision is made to attempt surgical removal soon after the injury, before there has been an opportunity for the development of infection, open thoracotomy is the method of choice. The method used by Villeon of inserting blunt forceps into the lung under fluoroscopic control, although apparently productive of good results, is unsurgical. After the object has been accurately localized, an intercostal incision of sufficient length to give an adequate exposure is made, the ribs are separated by a rib-spreading retractor, the lobe is grasped, and the foreign body is located by palpation. Hemorrhage is controlled and the object is brought into relief by compressing the surrounding lung tissue An incision is made in a radial direction from the hilum; the foreign body is grasped by forceps and removed Devitalized lung tissue is excised, large vessels and open bronchi are closed by suture ligatures, and the incision in the lung is carefully approximated by interrupted sutures. Intercostal catheter drainage is established and the chest wall is closed in layers

The operation should be done in stages if there is obvious infection. One or more ribs are resected over the object, the pleura is exposed for a distance on each side of the incision, and the area is packed with gauze. The skin is loosely approximated over the gauze, which is left in sufficiently long to cause adhesions to form between the parietal and visceral pleura. The lung is fixed to the parietal pleura by a ring of interrupted sutures and is incised, and the foreign body is removed The opening in the lung is lightly packed with gauze.

When such operations are carried out through an open pleural cavity, general anesthesia should be administered under slightly positive pressure, by intratracheal tube in adults and older children and with a snugly fitting mask in infants. Operations which do not necessitate open pneumothorax are very satisfactorily done under local and regional anesthesia

DRAINAGE OF LUNG ABSCESS

Before an attempt is made to drain a lung abscess, it is essential that the lesion be accurately localized by a careful study of roentgenograms made in various positions, as localization is usually impossible by physical examination alone. It is necessary to know not only the location of the abscess in relation to certain ribs, but how far it is from the surface and how to approach it at its most superficial point. Putrid lung abscesses lie in close contact with the visceral pleura and usually are also near the chest wall; but, in a small number, the visceral pleura nearest the abscess may be located in a pulmonary fissure or on the mediastinal side of the lung. When it is necessary to penetrate the lung tissue for more than 1 or 2 cm., it will be found that entrance was not made at the most superficial part of the abscess. It is also important to know whether the abscess cavity is unilocular or multilocular. If the cavity is multilocular, all the pockets must be opened and adequately drained.

These suggestions are important because of certain changes which take place as the result of the external drainage of lung abscesses, changes that affect primarily the effectiveness of cough. Under normal conditions, with the chest wall and lung intact, positive pressure is built up during the preliminary phase of cough. Following a full inhalation, there is a strong contraction of the muscles of expiration, especially the abdominal muscles. During this period the glottis is closed. At the time of cough the diaphragm is relaxed and the glottis opens, so that air is expelled through the tracheobronchial tree with force sufficient to remove the bronchial secretions or pus from the respiratory passages. Since lung abscesses usually communicate with bronchi of moderate size, an opening through the chest wall into the abscess cavity makes it impossible for the individual to develop a sufficiently positive intrabronchial pressure to expel pus or mucus from the adjacent air passages. Pus may therefore drain into dependent portions of the bronchial tree, setting up new areas of inflammation which may result in other abscesses or cause a diffuse suppurative pneumonitis. For these reasons it is desirable to complete operation for drainage of lung abscesses in one stage. The cavities are unroofed and packed with gauze. The gauze packing should be changed often enough to prevent its becoming saturated with pus.

While surgical drainage is most often indicated in the treatment of putrid lung abscess, it is at times of value in other pulmonary lesions. Lilienthal (1929) advised external drainage in certain large tuberculous cavities, especially those with marked secondary pyogenic infection. A similar procedure was sometimes carried out in large bronchiectatic cavities, which were causing toxemia and producing copious sputum. Drainage was advocated also in very large infected lung cysts. In these latter cases drainage still may be useful as a preliminary to extirpation in large infected cysts, as recommended by Eloesser. In chronic abscesses surrounded by subcavities and bronchiectasis, primary resection of the diseased lung tissue is now considered the treatment of choice. This also applies to most infected lung cysts.

Formerly, operation was reserved for chronic lung abscesses which did not respond to conservative measures. Neuhof and his associates were the first to report a relatively large number of acute abscesses treated by surgical drainage with

excellent results. It is now realized that the best results are obtained when abscesses are drained before the wall has become dense and inelastic and especially before irreversible changes have occurred in the surrounding lung tissue and bronchi.

Technic of Drainage of Lung Abscess

As previously stated, accurate localization is the most important part of the procedure for the drainage of lung abscesses. If the lesion is well localized and the approach to the abscess is made over its most superficial portion, the operation is simple and can ordinarily be completed in one stage. When the approach is made away from the most superficial portion of the abscess, the two layers of pleura may be found incompletely fused or not fused at all, and the operation will have to be done in stages, thereby adding to the danger of the undertaking and decreasing the chances of a satisfactory result. The operation is most satisfactorily done under regional and local infiltration anesthesia. A 1 per cent solution of procaine is used, with one drop of 1:1,000 epinephrine solution added to each 30 c.c. of the anesthetic solution. The intercostal nerves from the area are blocked proximal to the abscess, usually near the rib angles. As a rule it is necessary to inject only three, at most four, of these nerves. Skin wheals are made first over the inferior rib margins using a hypodermic needle; a 22 gauge, 5 cm. needle is then used for injection of the deeper tissues. The needle is carefully passed into the tissues overlying the inferior rib margin, and small amounts of anesthetic solution are injected along its course. Contact is made with the rib near its inferior border, and the needle is then deflected caudally so as to by-pass the rib margin. Anesthetic solution is again injected and this is continued as the needle is passed about 0.5 cm deep to the inferior border of the rib. A maximum of 10 c c. of anesthetic fluid is used for each intercostal space. The skin, subcutaneous tissues, and muscles are infiltrated in the proposed line of incision

The incision is made in line with the rib or ribs to be resected when entrance is to be made in front or in the axilla. When the approach is posterior, it may be better to use a vertical incision. An attempt is made to center the incision over the most superficial portion of the abscess. The rib or ribs are then exposed and resected subperiosteally. The internal periosteum is incised and the pleura is carefully inspected. If the pleura appears thick and there is no visible lung motion, the pleura is cautiously incised. If the parietal and visceral layers of pleura are fused, as should be the case, a needle is inserted into the abscess cavity. Usually only foul air is withdrawn, but this is sufficient evidence that the abscess has been entered. The periosteum and intercostal muscle are locally excised and the abscess cavity is opened and carefully palpated, especially with regard to the distance between its various parts and the pleura. A few mattress sutures of catgut are then inserted around the periphery of the abscess cavity and the roof or external wall is excised (Fig 364). All pus and necrotic debris are removed and the walls of the cavity are carefully inspected, the patient being asked to cough to see if pus is squeezed into the main cavity from subcavities If no subcavities are found, the skin is fixed to the cut edge of the pleura and the cavity is lightly packed with gauze, the skin and pleural margins being protected by petrolatum gauze. The gauze packing is changed at frequent intervals for the first few days.

If, when the pleura is first incised, it is found that there is incomplete adherence at the site of entrance, the small opening should be plugged immediately,

then covered with a thick layer of petrolatum gauze and the skin closed. If by chance considerable air enters the pleural space, the wound is packed with petrolatum gauze and the skin is left at least partially open. If a large quantity of air enters the pleural space, it is wise to change technic and aspirate, inserting the needle at a distance from the site of the incision.

In 1923 Graham recommended destroying areas of pulmonary suppuration with the actual cautery. In his original paper he referred especially to chronic lung abscess with multiple subcavities, but in later articles he recommended the use of the cautery in the treatment of certain cases of bronchiectasis and in some advanced cancers of the lung. With the marked improvements in the technic of pulmonary resection, the destruction of lung tissue by cautery is rarely indicated, and, even then, only for small localized areas. Small areas of lung tissue may be destroyed by the high frequency cautery, but only when the operation is being carried out under local anesthesia.

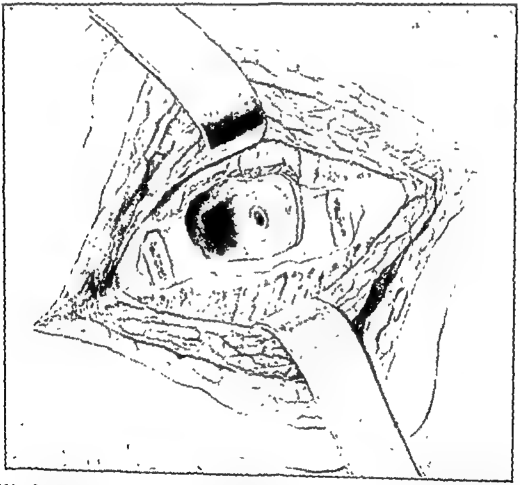

Fig 364.—Method of unroofing chronic lung abscess. The cavity is then packed snugly with plain gauze.

PULMONARY CYSTS

The term, pulmonary cyst, should be used to describe an abnormal space within the lung, the wall of which has a definite structure and which is lined in part or completely by epithelium. This epithelium may or may not be ciliated. The remainder of the wall varies considerably, but usually contains smooth muscle and cartilage, one or both. This anatomic structure strongly suggests that these

cysts are of bronchial origin. They are, in fact, often quite similar to so-called bronchiogenic cysts of the mediastinum, and the origin may be the same. The character of the wall and their frequent occurrence in early infancy indicate a congenital origin for the majority of these cysts; however, it may be that some of them develop later in life. The congenital cysts may be single, multiple, or diffusely spread throughout one or both lungs, the so-called polycystic lungs. The smaller cysts, even when present in considerable numbers, may produce no symptoms until they become infected or until some other complication arises. Infection is the most frequent complication. Since there is almost invariably a bronchial communication, though usually a small one, the source of infection is obvious. Ravitch states that

Fig. 365.—Roentgenogram of chest, diagnosed as giant cyst of left lung. At operation it was found that one segment of the upper lobe was markedly emphysematous, the result of a check-valve obstruction of the segmental bronchus

infection is practically inevitable. Once these cysts become infected, they behave as do other epithelium-lined cavities, that is, they give rise to recurrent bouts of fever, followed as a rule by the expectoration of considerable quantities of purulent sputum, which often is foul. Physical examination during one of these episodes may show little of diagnostic value. Roentgenograms may show that the cyst or cysts contain fluid or air or both. When both fluid and air are present, the picture may be confused with lung abscess, and many cysts have been drained surgically because of this mistake in diagnosis. On the other hand, certain large cysts are apt to simulate empyema and in the past many such cases have been drained because of that diagnosis. Not until Haight and Maier called attention to it was

Fig. 366.—Roentgenogram showing bilateral, diffuse pulmonary cysts.

Fig 367.—Roentgenogram of the chest of the patient shown in Fig. 366, a few days after enucleation of cysts of the right lung.

this mistake recognized, and futile attempts often were made to close what were supposed to be chronic empyema cavities. Now that there is more general awareness of this problem, this mistake is less often made. In certain very large infected cysts, drainage followed by extirpation may be justifiable, but primary extirpation usually is the treatment of choice. This may be accomplished by segmental resection, lobectomy, or pneumonectomy, depending upon their number, size, and distribution.

Next to infection the most important complication is respiratory difficulty, the result of compression of functional lung tissue, in the involved lung or in both lungs. This occurs as a result of a ball-valve effect at the narrow bronchial communication, which may cause cysts to become tremendously distended even to the point where they will cause suffocation if not adequately treated. These giant cysts not infrequently occur in infants and should be considered as a likely cause of dyspnea if a considerable portion of the chest is hyperresonant. (Fig. 365.)

Noninfected cysts frequently may be enucleated with satisfactory results and when cysts are diffusely distributed throughout both lungs, enucleation is the only treatment which is applicable (Figs. 366 and 367). Multiple cysts localized within one lobe or one lung usually are best treated by extirpation of the involved lobe or lung.

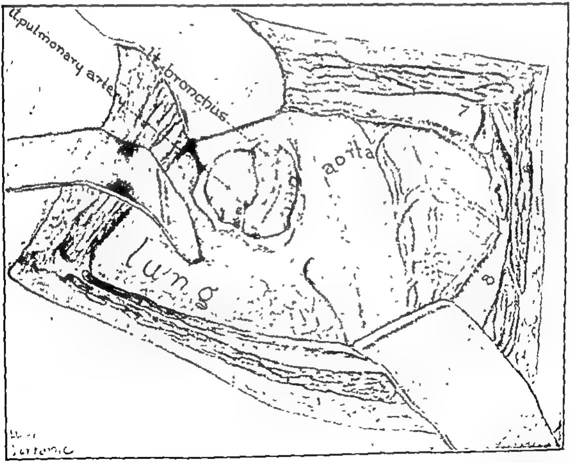

Fig 368.—Exposure of the left main bronchus, showing location of incision in bronchus.

BRONCHOTOMY

Occasionally, though rarely, it is desirable to open one of the main bronchi without interfering with the other hilar structures. It may be desirable to do this

for the removal of a foreign body which cannot be removed by bronchoscopy or when a competent bronchoscopist is not available. We have removed a wire staple by bronchotomy which could not be removed by bronchoscopy since the sharp points were directed upward and persistently entered the bronchial wall on attempts at extraction.

Either of the main bronchi may be exposed by turning the lung forward and making a small incision in the pleura where it passes from the chest wall to the hilum of the lung. On the left side, care must be exercised to avoid injury to the vagus nerve, and on the right the vagus nerve and the azygos vein must be protected. The bronchus is exposed by careful dissection and a longitudinal incision is made through the posterior membranous portion of the bronchial wall (Fig. 368). This incision should, of course, be located as accurately as possible over the tumor or foreign body. Before the bronchus is incised, the surrounding structures are thoroughly protected by gauze sheets. The incision in the bronchus may be closed by a continuous suture of fine silk or by closely spaced interrupted silk sutures. Intercostal catheter drainage is advisable.

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CHAPTER 33

PULMONARY RESECTION

I. A. Bigger

Until about fifteen years ago, surgical excision of the lung or a division of the lung carried a high mortality, and at one time it seemed that such operations might be unjustifiable except when dealing with malignancy. In 1925, Lilienthal, who did outstanding pioneer work in the development of lobectomy, reported thirty-four operations ranging in extent from partial resection of one lobe to total pneumonectomy. All were performed for the relief of extensive pulmonary suppuration, chiefly bronchiectasis and bronchiectatic abscesses. Thirteen, or 38 2 per cent, of these patients recovered, and twenty-one, or 61.8 per cent, of them died. Of twenty-six patients who had a single lobe removed, eleven, or 42.5 per cent, recovered, and fifteen, or 57.5 per cent, died. In spite of this high mortality, Lilienthal, Brunn, Whittemore, Archibald, Graham, and others continued their efforts toward improving the technic of pulmonary resection and the formulation of clearer indications for this type of surgery. As a result of their efforts and the more recent work of Alexander, Churchill, Shenstone, and others, the technic of lung resection was improved and the mortality was much reduced. A little more than fifteen years ago, Alexander collected the records of 116 patients operated upon in four clinics for unilateral bronchiectasis, with a mortality rate of less than 13 per cent, a most encouraging figure.

At about this same time there was considerable discussion in the literature as to the relative advantages of doing lobectomy in one or two stages. Churchill (1936) and Alexander (1933) favored the two-stage procedure, while Brunn and Shenstone advocated the one-stage operation. The latter had certain obvious advantages, but it had at least one serious disadvantage, the danger of the development of total empyema, which not infrequently was fatal.

With improvement in technic and since the advent of the sulfonamides and antibiotics, the morbidity and mortality following pulmonary resections have been remarkably reduced. As the results have improved, the indications for these various procedures have widened, and the limitations and contraindications have shown a corresponding decrease. The result has been an increase in the number of conditions treated by pulmonary resection. More radical procedures, especially as regards pneumonectomy, have been developed. These more radical procedures have in turn made it possible to accept more advanced cases, particularly of pulmonary malignancy, for surgery. The more extensive operations upon more advanced cases may well result in at least a temporary rise in morbidity and mortality, one of the apparently unavoidable cycles in surgical progress.

Lobectomy may be indicated in any of the following conditions: extensive trauma, especially when there is irreparable damage to the hilar structures to a lobe; chronic lung abscess; pulmonary cysts, especially when infected; bronchiectasis involving the greater part of a lobe; and fibrocavernous tuberculosis or tuberculoma, the active disease being essentially limited to a lobe. It is also indicated in certain cases of bronchial adenoma, sufficiently distant from the main bronchus to permit complete removal by lobectomy; hemangioma or congenital arteriovenous fistula limited to a lobe; isolated single metastatic tumors, especially sarcoma, when the primary lesion presumably has been destroyed; certain mycotic infections; and, rarely, peripheral primary bronchogenic carcinoma.

Pneumonectomy is most commonly indicated in the following: primary bronchogenic carcinoma; extensive unilateral bronchiectasis involving the greater part of one lung; extensive chronic pulmonary abscess involving a considerable part of a lung, including considerable portions of both or all lobes; and unilateral cystic disease involving the greater part of both or all lobes. Selected cases of unilateral fibrocavernous tuberculosis involving the greater portion of one lung may require pneumonectomy if the other lung is essentially free of disease. This also is true of tuberculosis of a main bronchus with stricture, the trachea, the opposite bronchus, and the opposite lung being essentially free of disease. Hemangioma or congenital arteriovenous fistula involving the hilar area and not removable by local excision or lobectomy, adenoma arising in a main bronchus and not removable by bronchotomy, and isolated single metastatic tumor, especially carcinoma, with the primary lesion apparently destroyed, also warrant pneumonectomy.

Indications for segmental resection of the lung are: most important, segmentally distributed bronchiectasis, especially when it is bilateral; pulmonary cysts; occasionally, tuberculomas; and, rarely, segmentally distributed fibrocavernous lesions.

Every effort should be made to diagnose and to determine the extent of pulmonary lesions preoperatively, for decision as to the extent of the resection, indeed the need for resection, cannot properly be made without this information, which may be difficult or even impossible to obtain at the time of thoracotomy. Furthermore, a knowledge of the character and extent of the pulmonary lesion helps the surgeon to decide upon the type and level of the thoracotomy incision. In certain conditions, such as chronic pulmonary abscess or tuberculosis with cavitation, it is important that the bronchus or bronchi draining the diseased area be occluded before the infected area is manipulated to any considerable extent. In such lesions, first consideration should be given to that approach which gives the best immediate exposure of the hilar structures, especially of the bronchi. However, if very dense adhesions are to be anticipated, one must also consider the accessibility of these adhesions In certain other lesions such as cellular, friable tumors, early occlusion of the veins is of primary importance.

LOBECTOMY BY THE TOURNIQUET TECHNIC

One of the important factors in the prevention of empyema after lobectomy was the development of a satisfactory technic for intrahilar dissection and individual ligation of the vessels as well as proper closure of the bronchial stump. Excision of a lobe by the tourniquet technic is simpler than the hilar dissection and ligation technic, but of necessity results in the mass ligation of tissue, with subsequent

necrosis of considerable parts of the tissue so ligated; hence the high incidence of infection. In addition, since it is not possible to properly close and cover the bronchial stump when the tourniquet technic is used, the bronchus more frequently opens up, resulting in a bronchopleural fistula, with all that this implies. For these very good reasons the tourniquet technic is rarely used now and should be used only under exceptional circumstances. However, since this technic may occasionally have to be resorted to, it is described below.

Lobectomy, especially lower lobe lobectomy, is usually carried out through a long posterolateral incision, through the sixth intercostal space or the bed of the sixth rib. It may be necessary to divide one or two ribs adjacent to the incision. *If so, they should be sectioned about 2 cm. from the transverse processes, and an* additional centimeter or so should be *removed from the medial (posterior) end,* or they should be fixed by wire sutures or by bone pegs. These measures are used to prevent postoperative pain from the divided rib ends rubbing together. When entrance is made through an intercostal space, the intercostal muscles and pleura are incised just above a rib to avoid the intercostal vessels and nerves. A gauze sheet is placed over the margins of the wound and the ribs are separated by a rib-spreading retractor. The adhesions between the diseased lobe and the surrounding structures are separated by blunt and sharp dissection, but the heavier bands should be doubly clamped, divided, and ligated. In lower lobe bronchiectasis the densest adhesions are usually found between the base of the lower lobe and the diaphragm. The inferior pulmonary ligament, which extends from the lower border of the hilum of the lung to the diaphragm, is doubly clamped, divided, and ligated. The diaphragm may be temporarily paralyzed by pinching the phrenic nerve as it courses downward across the lateral surface of the pericardium; however, this usually is *unnecessary and may be inadvisable since activity of the diaphragm helps keep* the remaining lobe or lobes expanded. Difficulty is encountered not infrequently in separating the lobes one from the other, and this part of the operation should be carried out with special care to avoid injury to that portion of the lung which is to be left in.

After the diseased lobe is separated as completely as possible from the surrounding structures, a specially designed pulmonary tourniquet is applied as close as possible to the hilum and another one is placed 4 to 5 cm distal to the first (Fig. 369). The second tourniquet is used to prevent pus from escaping when the bronchus is divided. The lobe is divided so as to form an inverted cone with its apex at the proximal bronchial stump, which should project only a short distance beyond the tourniquet. An attempt should be made to ligate individually the larger branches of the pulmonary artery (Fig 370), but they do not stand out if the hilum is indurated and a considerable number of them will be missed. For this reason, it is important to apply deep sutures to prevent bleeding from the unligated vessels. The pleural covering of the bronchial stump is carefully approximated with interrupted sutures of chromic catgut or silk. Two rows of sutures are used; the deeper sutures should interlock and the other row should be so placed as to approximate the pleural surfaces. Brunn advised that the stump be sutured *to the undersurface of the adjacent lobe.*

After it has been demonstrated that the stump does not bleed and that air does not escape, two intercostal tubes are inserted for closed drainage, one antero-

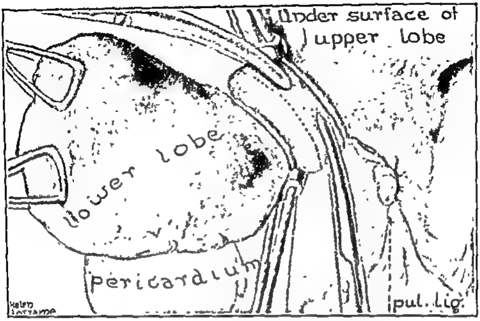

Fig. 369.—Lobectomy, left lower lobe. Note that clamps are applied distal to the proximal tourniquet to prevent the tourniquet's slipping off.

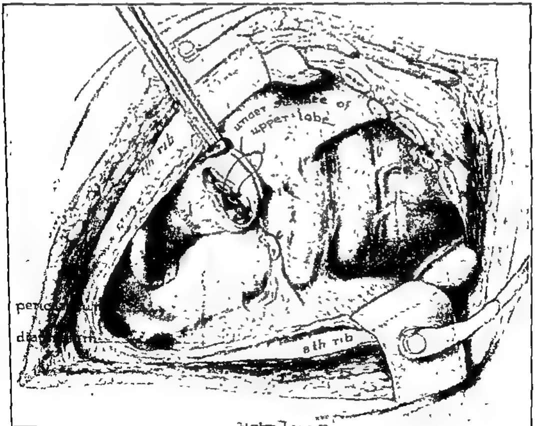

Fig. 370.—Lobectomy. Method of closure of pedicle of lobe

laterally above and one posterolaterally below. The chest wall is closed with heavy pericostal sutures to approximate the ribs and pleura, and interrupted sutures for the muscles, fascia, and skin.

PULMONARY RESECTION BY INTRAHILAR DISSECTION AND INDIVIDUAL LIGATION TECHNIC

The technical difficulties encountered in pulmonary resection by the intrahilar dissection and individual ligation technic are inversely proportional to the size of the pulmonary segment being removed. *Pneumonectomy is technically easier than lobectomy or segmental resection but has a higher mortality and morbidity than either of these procedures, especially in older individuals.*

Fig. 371 —Position of the structures in the hilum of the left lung.

This important advance in technic was the result of work by many individuals. Rienhoff. Churchill and Belsey, Blades and Kent, Edwards, Nelson, Overholt, and others had important parts in the development of the hilar dissection and individual ligation technic.

The surgeon must be familiar with the anatomic position and relations of the various hilar structures (Figs. 371 and 372), and since the position and relations of

the bronchi, arteries, and veins are different in each lobe, he must acquaint himself with all of them.

Every effort should be made to diagnose and to determine the extent of pulmonary lesions preoperatively, for decision as to the extent of the resection, indeed the need for resection, cannot properly be made without this information, and such information may be difficult or even impossible to obtain at the time of thoracotomy. Furthermore, a knowledge of the character and extent of the pulmonary lesion helps the surgeon to decide upon the type and level of the thoracotomy incision. In certain conditions, such as chronic pulmonary abscess or tuberculosis with cavitation, it is important that the bronchus or bronchi draining the diseased area be occluded before the infected area is manipulated to any considerable extent. In such lesions first consideration should be given to that approach which gives the best immediate exposure of the hilar structures, especially of the bronchi. However, if very dense adhesions are to be anticipated, one must also consider the accessibility of these adhesions. In certain other lesions such as cellular, friable tumors, early occlusion of the veins is of primary importance.

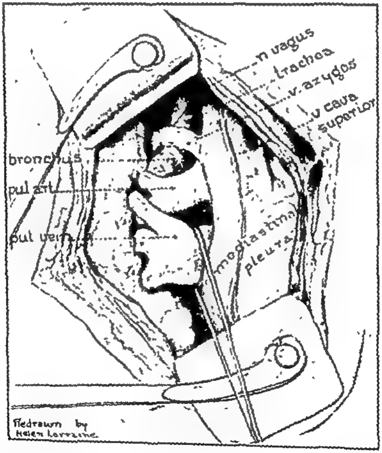

Fig. 372.—Relation of the structures which make up the hilum of the right lung The mediastinal pleura has been omitted over the vessels to show these structures more clearly

PNEUMONECTOMY

For pneumonectomy the author usually prefers the anterolateral approach, but if there is reason to expect dense adhesions between the lower lobe and diaphragm, or in the cardiophrenic angle, the posterolateral incision may be preferable. There

are differences in the technical problems encountered on the two sides, dependent upon certain anatomical peculiarities. Generally speaking, excision of the left lung is apt to be somewhat less difficult than excision of the right lung, chiefly because the left pulmonary artery is more readily exposed and the left main bronchus is longer than the right. The technic of pneumonectomy varies to some extent, depending upon the condition for which it is done. When pneumonectomy is done for nonmalignant lesions, extensive removal of the mediastinal nodes and lymphatic-bearing tissue is considered unnecessary, but when done for malignancy, especially for primary bronchogenic carcinoma, wide removal of these tissues is essential. The decision as to whether or not to remove a lung, the seat of carcinoma, is not always easy, even when the chest is opened. For example, enlargement of the hilar and mediastinal lymph nodes does not necessarily mean they contain metastatic cancer. When there is reasonable doubt on this point, it may be necessary to remove a node for microscopic study. When there are metastatic nodes in the mediastinum well removed from the hilum of the lung, the lesion is almost certainly incurable. Yet in deciding whether or not to remove such a lung, one should consider the age and general condition of the patient, the degree of malignancy of the tumor, and the extent of secondary infection in the involved lung. If the tumor is obviously highly malignant, this should be considered as evidence against lung removal. On the other hand, a lung containing multiple abscesses or a large single abscess distal to the tumor may justifiably be removed for palliation.

TECHNIC OF PNEUMONECTOMY BY ANTEROLATERAL INCISION

This approach is described under the section on thoracic incisions, but it should be stressed here that the level of entrance into the thorax should be based on the site of the disease. Also, the exposure may be greatly improved, by dividing one or more cartilages at the sternum. Repair of the divided cartilages adds little to the difficulty of closure or to postoperative discomfort. For satisfactory exposure the intercostal structures must be separated from the upper border of the rib below the level of entrance into the thorax, as far back as the rib angle or even beyond. The exposed ribs are covered with gauze sheets, the rib-spreading retractor is inserted, and the ribs are slowly separated. If the retractor is widely opened at once, the adjacent ribs may be fractured, and this will cause additional postoperative discomfort. When the lung is adherent at the site of entrance, it must be freed for a considerable distance on each side of the incision; otherwise, the lung may be torn when the ribs are widely separated.

An effort is now made to determine the character and extent of the pulmonary lesion and, in carcinoma cases, to determine whether or not the lesion is operable The hilum and the adjacent mediastinum are carefully examined for metastatic nodes and for fixation to other structures, such as the pericardium. Involvement of the pericardium alone does not mean the lesion is inoperable, but extension into the pulmonary veins does have that significance The degree of fixation to the chest wall over the site of the tumor also is determined.

If the lesion appears to be operable, attention is directed to the hilar structures. (Fig. 373.) On the left side the pulmonary artery occupies the anterior-superior position, and since there is sufficient length it is simpler to secure adequate room

for division between ligatures than on the right side. The mediastinal pleura is incised perpendicularly anterior to the hilum and posterior to the phrenic nerve. The pleura is dissected up on both sides of the line of incision, exposing the pulmonary artery, which is carefully separated from the adjacent structures, directing

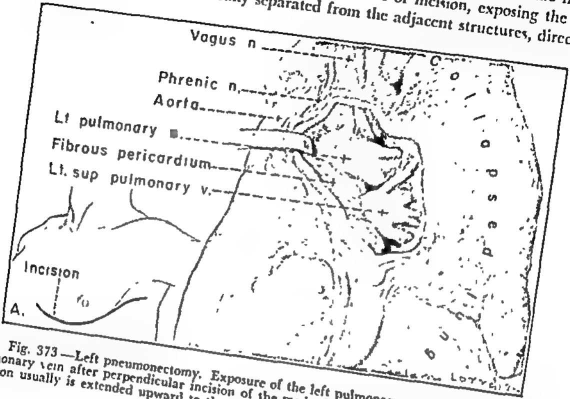

Fig. 373.—Left pneumonectomy. Exposure of the left pulmonary artery and left superior pulmonary vein after perpendicular incision of the mediasinal pleura. The sternal end of the incision usually is extended upward to the upper border of the third costal cartilage.

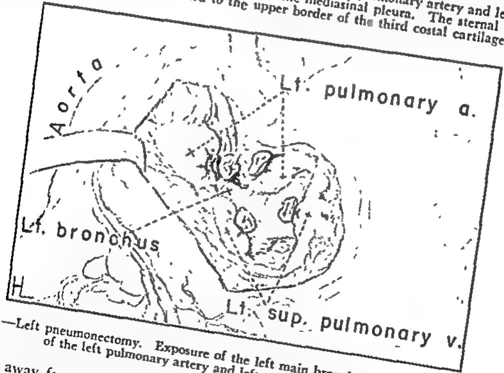

Fig 374.—Left pneumonectomy. Exposure of the left main bronchus by ligation and division of the left pulmonary artery and left superior pulmonary vein.

pressure away from the arterial wall. This part of the dissection must be done with the greatest care for injury to the artery at this stage creates a very difficult situation. A small piece of gauze rolled into a rounded mass and caught in the tip of a strong clamp is especially useful in this type of dissection. After the artery

has been completely encircled, a piece of narrow tape or heavy braided silk is passed around it for traction and the vessel is separated from the other structures both proximally and distally so as to gain adequate length for division between ligatures. It is advisable to free up a sufficient length of artery to permit a stump to project beyond the proximal ligatures for a distance approximately equal to the diameter of the vessel. Number 5 or 6 braided silk should be used as ligature material. In

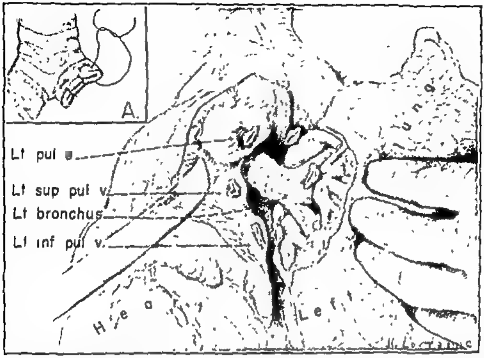

Fig 375.—Left pneumonectomy. The left pulmonary vessels have been ligated and divided. The left main bronchus has been dissected out to the carina and occluded just distal to the carina by mattress sutures of silk, using four or five sutures. Inset shows bronchus closed

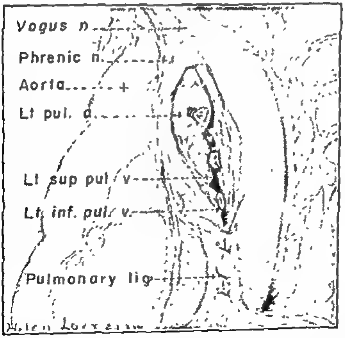

Fig. 376.—Left pneumonectomy Closure of mediastinal pleura. It is important that the pleura be well approximated over the bronchial stump Fixation of the pleura to the bronchial stump by suture seems unnecessary

addition to the plain ligatures, a suture ligature of 00 or 000 silk should be used on the proximal side. The left superior pulmonary vein is next dissected out and a heavy traction ligature is placed around it, but usually it is not tied at this time. The bronchus is now exposed and is dissected out to the carina. (Fig. 374.) The bronchial arteries are looked for and are carefully ligated The bronchus is now completely occluded by a row of mattress sutures of doubled 000 silk (Fig. 375). These sutures should be placed immediately adjacent to the carina and are so inserted that they approximate the posterior membranous wall to the curved cartilaginous wall. A heavy right-angled clamp is applied to the bronchus distal to the line of mattress sutures and the bronchus is divided 5 or 6 mm. from the suture line by a sharp knife. Simple interrupted silk sutures are now used to approximate accurately the walls of the proximal segment. Phenol and alcohol are applied to the distal stump, and attention is directed to the inferior pulmonary vein, which is dissected out, carefully ligated, and divided. If the main vein is especially short, it is desirable to dissect out the primary branches and apply ligatures to each of them as well as to the main vein. The superior pulmonary vein is now divided between ligatures. The remainder of the procedure may be varied depending upon the associated findings. In inflammatory conditions or other nonmalignant lesions, the posterior pleural reflection may be divided, adhesions separated between the lung and chest wall, and the lung removed. In nonmalignant lesions adequate pleura should be saved to cover the divided hilar structures, especially the bronchial stump. This is especially important on the right side since the right bronchial stump is more superficial than the left. (Fig. 376.)

In carcinoma of the lung one may take either of two courses If the lung is bulky, it is better to proceed as just described. After adequate space has been gained by removal of the lung, an incision is made through the pleura over the upper mediastinum and the pleura, and all lymphatic-bearing tissue including that along the trachea, in the arch of the aorta, between the main bronchi and that adjacent to the opposite main bronchus is dissected out and removed. Removing the lung and this lymphatic-bearing tissue separately [illegible], but is safer than [illegible]. If the lung is not b[illegible] vessels and the bronchus as described, then diss[illegible] the lymphatic-bearing tissue and remove it with the lung. Unless the left recurrent laryngeal nerve is in intimate contact with tumor tissue, it should be carefully preserved. From the standpoint of cancer surgery the most ideal procedure would be to start the dissection peripherally, carrying it toward the hilum from all sides, then divide the hilar structures, thus removing the lung and regional lymphatics in one block. Unfortunately, this frequently is not feasible.

When areas of fusion between the visceral and parietal pleurae are encountered, especially when dealing with cancer, it is better to incise the parietal pleura adjacent to the fused area and thus deliberately carry the dissection into the extrapleural plane. If this dissection is done with proper care, applying pressure against the pleura, either with the finger tips or with a gauze dissector, the fused areas can be removed without undue bleeding. Furthermore, it is better in severe inflammatory lesions, and especially in malignancy, to remove such obviously involved pleura. Unless there has been very gross contamination, the chest cavity need not be

drained after pneumonectomy. If drainage is omitted, the patient must be carefully watched, and should fluid accumulate in quantity sufficient to cause mediastinal displacement and circulatory and respiratory embarrassment, it should be removed by thoracentesis to relieve pressure symptoms. Occasionally, thoracentesis will have to be repeated several times. The divided cartilages are sutured, using 32 gauge stainless steel wire. The cartilages and corresponding ribs adjacent to the incision are approximated by pericostal sutures of heavy chromic catgut and the muscles and fascia are approximated with fine interrupted sutures. There are several points of difference between left and right pneumonectomy. The operative risk on the right is somewhat greater, due to anatomical differences between the two lungs. The lung volume on the right is greater and the volume of blood passing through the right pulmonary artery is also somewhat greater. Extirpation of the right lung therefore results in a greater reduction in lung volume and breathing capacity, and sudden occlusion of the right pulmonary artery presumably places a slightly greater burden on the right ventricle. Also it is sometimes more difficult to obtain an adequate length of right pulmonary artery for safe ligation, and the right bronchial stump lies more superficially and is therefore more apt to open, giving rise to a pleurobronchial fistula, always a serious matter. When the right chest has been opened and explored and pneumonectomy is decided upon, the mediastinal pleura is incised perpendicularly, just posterior to the phrenic nerve, and the azygos vein, which curves forward around the upper border of the hilum, is divided between ligatures. Division of this vein is not absolutely necessary in nonmalignant disease of the lung but it releases that part of the superior vena cava which must be freed up and retracted forward in order to gain an adequate length of pulmonary artery for safe division between ligatures. Since the right superior pulmonary vein overlies the lower portion of the pulmonary artery, it is better to free it up and place a traction ligature around it before attempting to free the pulmonary artery. It is essential that the right bronchial stump be covered by pleura, and therefore, if the mediastinal pleura has to be removed, a flap of pleura should be turned up from the chest wall and sutured over the bronchus.

RIGHT UPPER LOBECTOMY

Excision of the right upper lobe may be performed satisfactorily through either an anterolateral or a posterolateral incision. The anterolateral approach, entering the thorax through either the third or the fourth intercostal space, then dividing the fourth and, if necessary, the third costal cartilage, gives satisfactory exposure. The mediastinal pleura is incised perpendicularly posterior to the phrenic nerve, and the superior pulmonary vein is carefully dissected out and a traction ligature of narrow tape is placed around it. The vein is gently retracted anteriorly and caudally, and the anterior superficial branches, usually two, are freed up, but are not immediately ligated (Fig 377.) The first branch of the right pulmonary artery, usually the common stem of the apical and anterior segmental arteries, is dissected out. Since this common trunk is short, it is necessary to liberate its primary divisions for a sufficient distance to permit the application of ligatures. If the main stem artery is of sufficient length, it should also be ligated. The branches are then divided between the ligatures. If the oblique fissure is well developed, it is best to approach the posterior segmental artery from that site. The pleura is

incised and the artery is carefully dissected out. It usually arises distal to the apical-anterior trunk, but proximal to the arteries of the middle lobe and to the apical segment of the lower lobe. However, it may arise from the apical anterior trunk. In other words, all of the segmental arteries of the right upper lobe may come off one main trunk. On the other hand, the posterior segmental artery may have a common origin with the artery to the apical segment of the lower lobe.

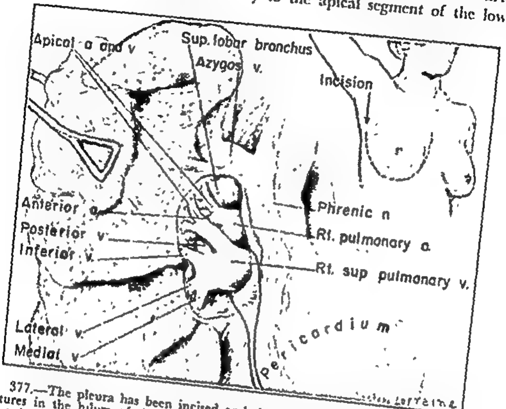

Fig 377.—The pleura has been incised and the lung tissue dissected laterally to expose the structures in the hilum of the right upper lobe. Also shown are the middle lobe veins which are tributaries of the superior vein.

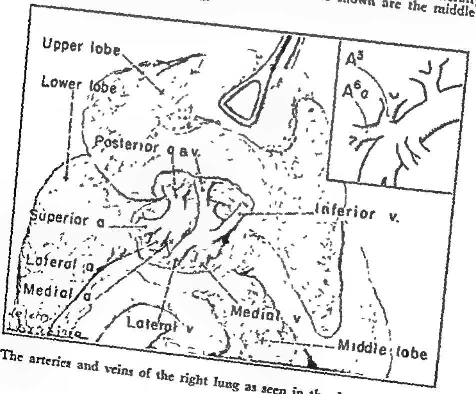

Fig 378.—The arteries and veins of the right lung as seen in the depths of the major fissure.

(Fig. 378.) In the majority of instances, it will be discovered arising from the interlobar portion of the right pulmonary artery as an independent branch. It should be divided between silk ligatures.

The superficial branches of the superior pulmonary vein which have previously been dissected out are now divided between ligatures, care being taken to avoid injury to the tributary of the superior vein from the middle lobe. The upper lobe bronchus is now closed by a series of interlocking mattress sutures, and the segmental bronchi are closed by heavy ligatures. If the main upper lobe bronchus is exceptionally short, it may be better to occlude only the segmental bronchi and divide them between ligatures. It is usually better to close the main bronchus by mattress sutures, then divide it immediately distal to these sutures or section each segmental bronchus near its origin and close the ends by interrupted silk sutures. (Fig. 379.)

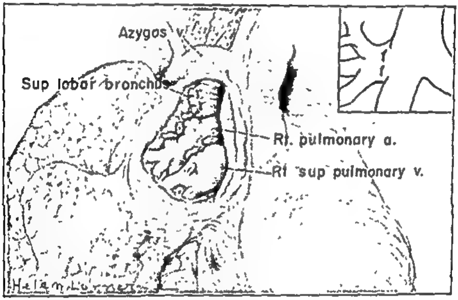

Fig 379.—The structures in the hilum of the right upper lobe have been divided and the lobe has been removed The middle lobe arteries and veins and the artery to the superior segment of the lower lobe are shown Note that the middle lobe and superior segment arteries arise at the same level

In case the posterior upper lobe vein has not previously been secured, it should now be divided between ligatures. The lobe is then separated from the lower and middle lobes and removed During this separation from the other lobes small veins may be encountered crossing from one lobe to another and these should be carefully ligated. A raw surface of considerable size may be left on the middle lobe, but, as demonstrated by Overholt, it is best not to suture this

The stump of the upper lobe bronchus should be carefully covered by pleura, if necessary by fashioning a flap of parietal pleura for that purpose. The pleural space is drained by two intercostal catheters, one in the anterior axillary line above and one in the posterior axillary line below. The divided cartilages are sutured to the sternum, preferably by 32 gauge stainless steel wire.

MIDDLE LOBE LOBECTOMY

The middle lobe is most satisfactorily exposed through an anterolateral incision, entering the chest cavity through the fourth or fifth intercostal space and

dividing one or two cartilages as indicated. The mediastinal pleura is incised perpendicularly and the tributary of the superior pulmonary vein, which drains the middle lobe, is dissected out and a traction ligature is placed around it. At this point the technic may vary depending on whether or not the oblique fissure is obliterated by adhesions. When that fissure is the site of dense scar, the middle lobe vein is drawn forward and upward and the bronchus is exposed and carefully freed up. Obstructing mattress sutures are applied proximally and the bronchus is obstructed by a clamp 3 or 4 mm. distal to the suture line, and the bronchus is divided against the clamp. Closure of the proximal end is completed by two or three interrupted sutures of 000 silk. The arteries to the middle lobe arise from the interlobar portion of the pulmonary artery lateral and posterior to the middle lobe bronchus. The arteries may originate from a common trunk or may arise separately. When the bronchus has been divided, the arteries come into view and are divided between ligatures. The vein is next divided between ligatures and the lobe is separated from the other lobes and removed. When the depth of the oblique fissure is readily exposed, the arteries and bronchus are more satisfactorily exposed by elevating the middle and upper lobes and incising the pleura in the mid portion of the oblique fissure. First the arteries, then the bronchus are divided. The bronchial stump may be covered by suturing the undersurface of the upper lobe over it or by turning a flap of mediastinal pleura over it. The pleural space is drained by one or two intercostal catheters and closed as previously described.

It should be noted that the middle lobe vein sometimes does not join the superior vein but enters the auricle directly.

RIGHT LOWER LOBECTOMY

Right lower lobectomy is usually performed through a posterolateral incision. This incision is always preferable when there is a likelihood of dense adhesions between the lung and diaphragm, particularly in the cardiophrenic angle. The arteries to the apical and basal segments of the lower lobe are most readily exposed in the oblique fissure, where the horizontal fissure joins it. The two arteries must be ligated separately since the artery to the middle lobe arises anteriorly at about the same level that the artery to the superior segment of the lower lobe arises posteriorly. The visceral pleura is incised in the depth of the fissure, the inferior pulmonary artery is exposed, and the middle lobe artery and the artery to the superior segment are dissected out sufficiently to permit identification. The artery to the superior segment is dissected out to its branches before it is ligated, since the artery to the posterior segment of the upper lobe occasionally takes its origin from the artery to the superior segment of the lower lobe. After proper identification the superior segmental artery is divided between silk ligatures and the artery to the basal segments is then dissected out and a heavy silk ligature is applied to the main trunk However, the medial basal segmental artery arises only a short distance distal to the arteries to the middle lobe and superior segment of the lower lobe and usually requires separate ligation The basal artery may then be ligated distally and divided, or, if it is very short, the other basal segmental branches are ligated individually The lobe is now turned forward and the inferior pulmonary vein is dissected out and ligated. This vein is usually short and so it is safer also to apply ligatures to its segmental tributaries. The main vein is then divided as far distally

as possible or, if it is unusually short, the segmental veins may be divided at their junction with the main vein. The inferior pulmonary ligament is clamped, divided, and ligated. Should the lower lobe be approached through an anterolateral incision or should there be unusually dense adhesions posterolaterally, the inferior pulmonary vein is readily exposed and ligated by retracting the lobe laterally and posteriorly.

As with the arteries, the bronchi to the superior and basal segments have to be treated separately. The bronchi are usually most readily exposed in the oblique fissure for they lie immediately posterior to the arteries and, when the arteries have been ligated and divided, the bronchi are in the operative field. They are freed up, occluded by mattress sutures of doubled 000 silk, clamped or ligated distal to the suture line, and cut across a few millimeters distal to the line of occluding sutures. Closure of the bronchus is completed by a few interrupted sutures for approximation of the cut ends of the membranous and cartilaginous walls.

The lower lobe is now separated from the other lobes and from the chest wall and diaphragm and is removed. The bronchial stump is sutured to the undersurface of the upper lobe. The pleural space is drained by two intercostal catheters, one anterolaterally and one posterolaterally.

BILOBECTOMY

It not infrequently is advisable to remove the lower and middle lobes together. This procedure, first described by Churchill and later by Lindskog, is technically little more difficult than excision of the lower lobe. It is readily accomplished through either an anterolateral or a posterolateral incision. Should the anterolateral incision be used, the chest cavity should be entered through the fifth or sixth intercostal space and two or more cartilages should be divided near the sternum. The superior vein is exposed through a perpendicular incision in the mediastinal pleura and the tributary from the middle lobe is identified and dissected out but is not immediately ligated. A traction ligature is placed around it. The oblique fissure is now entered and the visceral pleura is incised. The pulmonary artery is dissected out and the posterior segmental artery of the upper lobe is identified. This is necessary since it may arise near the level of the artery to the middle lobe and the artery to the superior segment of the lower lobe, or even from the latter vessel. It is usually best to divide the arteries to the middle lobe between ligatures so as to gain a better exposure. Should the artery to the posterior segment of the upper lobe arise near the same level as the arteries to the middle lobe and superior segment of the lower lobe, both of these vessels must be individually ligated. Should the artery to the posterior segment of the upper lobe arise from the superior segmental artery, the latter vessel must be ligated distal to the combined trunk. The main pulmonary trunk is then divided between ligatures distal to the artery to the superior segment of the lower lobe. As previously noted, it may be necessary to ligate one or all of the basal arteries separately. The inferior pulmonary vein is dissected out and divided as previously described, and the tributary from the middle lobe to the superior vein is divided between ligatures. The transverse fissure is now developed and the bronchus is exposed above the origin of the middle lobe and superior segment bronchi. It is occluded by mattress sutures of silk and divided, and the middle and lower lobes are separated from the adjacent structures and removed. Intercostal drainage is established by anterolateral and posterolateral catheters.

LEFT UPPER LOBECTOMY

Left upper lobectomy may be accomplished satisfactorily through either an anterolateral or a posterolateral incision. The author prefers the anterolateral approach (Fig. 380). The chest cavity should be entered through the third intercostal

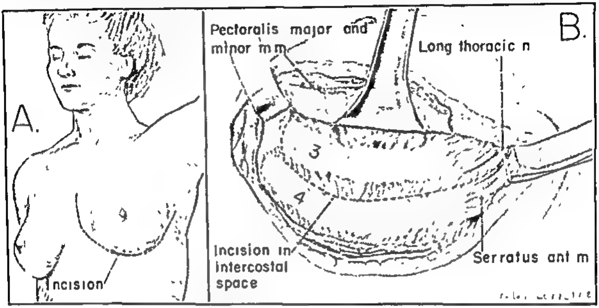

Fig. 380.—Anterolateral incision. The sternal limb of this incision may be extended upward to whatever level seems necessary; usually it extends to the upper border of the third costal cartilage. The axillary limb of the incision must be carried well up in the axilla and to near the posterior axillary line

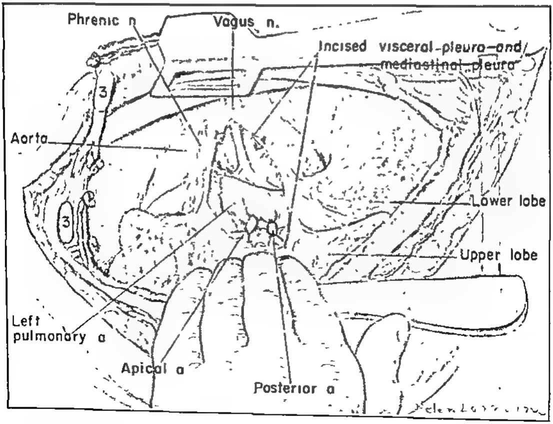

Fig. 381.—The apex of the left lung has been pulled forward and downward. The pleura has been incised to expose the apical and posterior segmental arteries at their origin from the superior surface of the left pulmonary artery.

space, the third costal cartilage being divided at the sternum. Preliminary to dissection of the lobar hilar structures, it is advisable to dissect out the main trunk of the superior pulmonary vein and the left pulmonary artery, placing traction ligatures around each of them. Following this the dissection is carried laterally along the superior surface of the pulmonary artery to expose the apical posterior segmental arteries, which may arise by a short common trunk or separately (Fig. 381). The

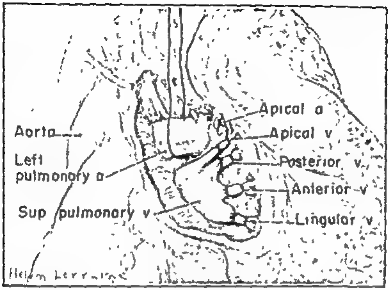

Fig. 382.—The apical and posterior segmental arteries have been divided. The upper lobe is retracted laterally and the segmental tributaries of the superior pulmonary vein have been ligated.

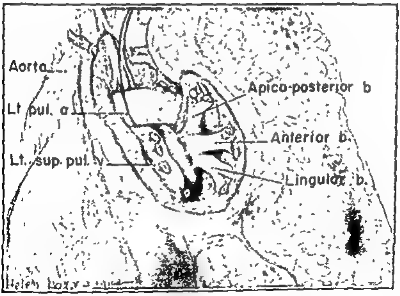

Fig 383.—The upper lobe bronchus has been occluded by mattress sutures near its origin.

apical artery is usually readily exposed by lateral dissection and there is no particular interference from other hilar structures. It should be doubly ligated with medium silk, 000 or 00, and divided between these ligatures. It often is possible to isolate and ligate the posterior artery in the same manner as described for the apical division, but at times its exposure is simplified by ligation and division of the apical vein which crosses the corresponding artery anteriorly. Attention is now directed to the inter-

lobar fissure where the anterior segmental artery and the arteries to the lingular segments are usually most readily exposed (Fig. 382). However, in cases of complete fusion of the two lobes by dense adhesions, the anterior and lingular segmental structures may be exposed by continuing the dissection laterally and then distally along the left pulmonary artery. However, this requires ligation and division of

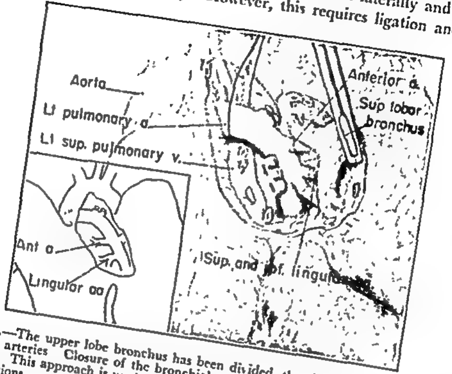

Fig 384.—The upper lobe bronchus has been divided, thereby exposing the distal upper lobe segmental arteries Closure of the bronchial stump has been completed with a few interrupted sutures. This approach is used only when the interlobar fissure is completely obliterated by dense adhesions.

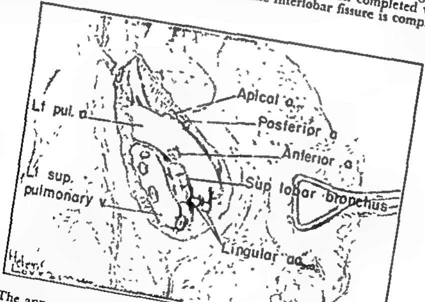

Fig 385—The appearance of the hilar structures after removal of the left upper lobe.

the apical posterior and anterior segmental veins, and the apical posterior and anterior segmental bronchi before ligation and division of the anterior segmental artery (Figs. 383 and 384). It also requires the same sequence in dealing with the hilar structures to the lingular segment. This sequence is undesirable and is justifiable only under exceptional circumstances. The usual procedure then is to

incise the interlobar pleura in the depth of the fissure and thus expose the remaining segmental arteries, which are doubly ligated and divided. The anterior artery and both lingual arteries may arise by a short common trunk, or all may arise separately. This is of little practical significance, for all of them must be dissected out and individually ligated since the common trunk, when present, is too short to be satisfactorily ligated and divided. The bronchi lie immediately superficial to the arteries and so are next occluded by sutures proximally and by heavy ligatures or clamps distally, and divided. The veins are then divided between ligatures and the lobe is separated from the adjacent structures and removed (Fig 385). Since the superior pulmonary vein drains only the upper lobe, the main vein and its chief tributaries are ligated. The bronchial stump must be well covered and this is usually best done by using a flap of mediastinal pleura.

In case of dense fusion of the two lobes by scar, all of the hilar structures of the upper lobe are divided, as described, and are used for retraction while the lobes are being separated. It should be noted that the number of segmental arteries to the left upper lobe which have to be ligated and divided may vary from three to seven, but there are most often five. Taking all factors into consideration, it is probable that left upper lobectomy presents greater technical difficulties than does removal of any of the other pulmonary lobes.

LEFT LOWER LOBECTOMY

The left lower lobe is best removed through the posterolateral approach. The fissure is entered and the pulmonary artery and its interlobar branches are exposed. It is necessary to ligate separately the artery to the superior segment and the artery to the basal segments, since the superior segmental artery arises at about the level of or even at a higher level than the lingular arteries (Fig 386). It is also usually advisable to ligate separately at least one of the basal segmental arteries.

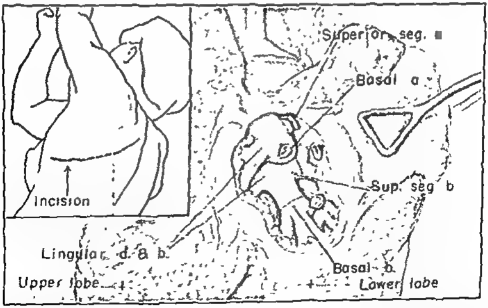

Fig. 386.—Left lower lobectomy Exposure of the arteries and bronchi in the depths of the main fissure Note that the superior segment and middle lobe arteries and bronchi arise at approximately the same level.

The bronchi usually will need to be treated in much the same manner as the arteries, that is, by separate closure and division of the superior segmental and basal bronchi. However, it may be possible to satisfactorily deal with the main lower lobe bronchus since the bronchus to the superior segment occupies a relatively more distal position than does the corresponding artery. The vein is somewhat more easily approached from the posterior side (Fig. 387). It is short and it is generally safer to ligate the main trunk and its immediate tributaries. The lobe is now separated from the adjacent structures and removed.

The chest cavity is drained by intercostal catheters placed anterolaterally and posterolaterally. It is frequently necessary to remove the lingular division of the upper lobe in conjunction with left lower lobectomy. This is satisfactorily accomplished either through an anterolateral or a posterolateral incision.

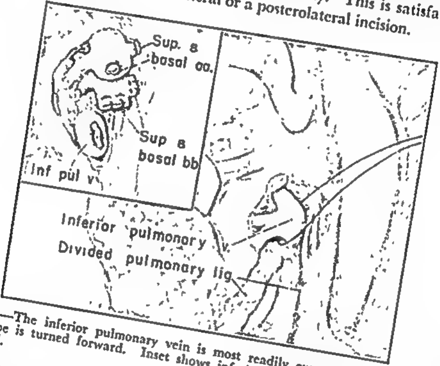

Fig. 387.—The inferior pulmonary vein is most readily exposed posteriorly. For this purpose the lobe is turned forward. Inset shows inferior pulmonary artery ligated and the bronchus closed.

RADICAL PNEUMONECTOMY

As was indicated in the preliminary discussion relative to pulmonary resection, more radical operations are now being done in certain patients with bronchogenic carcinoma. Not infrequently it is found that peripheral carcinomas of the lung have invaded the adjacent portion of the chest wall, at times with little or no evidence of metastasis to the regional lymph nodes. Under these circumstances it seems advisable to resect the involved portion of the chest wall and remove it in continuity with the lung. Reports by Coleman and others appear to support the idea that such operations are justifiable.

Numerous surgeons have resected considerable portions of the parietal pericardium, ligating the pulmonary vessels within the pericardial space and removing the segment of pericardium in continuity with the lung and the mediastinal lymphatic-bearing tissue. However, it remained for Allison to give a concise description of the anatomic relations between the pulmonary vessels and the pericardium. Allison also gave a detailed account of the technic of intrapericardial ligation of the pulmonary vessels. He recommends preliminary exposure and occlusion of the main bronchus by

heavy ligatures to avoid the spill-over of infected material into the opposite bronchial tree. The ligature is placed on the bronchus above the level of gross tumor, but no attempt is made to apply it at the level at which the bronchus will finally be divided. On the left side the pericardium is incised in front of the phrenic nerve and in line with it. This incision is extended below the level of the hilum of the lung, dividing the phrenic nerve and the accompanying vessels between ligatures. The pericardium is retracted laterally and the superior and inferior veins are identified. The reflection of serous pericardium between the veins is opened and the index finger is passed around the superior vein. The serous pericardium is now further incised until an adequate length of vein is available for division between ligatures. Suture ligatures of silk are also used. The pericardial incision is extended upward over the pulmonary artery and the index finger is passed around the artery anteriorly, superiorly, and posteriorly and then inferiorly, where it will be covered only by serous pericardium, which is incised. A sufficient length of vessel is then freed up to ensure safe division between ligatures. The inferior pulmonary vein is now stripped out and ligated. Allison mentions possible difficulty in gaining adequate exposure of the left inferior vein through the anterolateral approach. However, this difficulty usually is relatively slight and may be largely overcome by tilting the table so that the left side is considerably higher than the right, along with temporary reduction of the intrabronchial pressure. If the exposure still is unsatisfactory, transient gentle retraction of the heart may be necessary. The pericardium overlying the left main bronchus is incised and the lymphatic-bearing tissue between the main bronchi and below the aortic arch is dissected down to be removed with the lung. The left main bronchus is then occluded at the carina and divided and the pericardium is incised posteriorly so that the lung is completely separated from the mediastinum. If there are any remaining adhesions between the lung and the chest wall or diaphragm, these are divided and the lung is removed. No attempt is made to close the pericardium, but it is advisable to prevent possible extrusion of the apical portion of the heart into the pleural space by placing a few sutures across the space between the pericardial segments. Obviously these sutures should not be tied under tension

There are two significant differences in the technic of intrapericardial ligation between the right and left sides. On the right side the pericardial incision passes backward above into the angle between the superior vena cava and the right pulmonary artery. The fibrous pericardium between the two vessels is divided and the serous pericardium is incised in the anterior fornix The index finger can then be passed into the postcaval space and the artery thus exposed for division between ligatures. Also on the right the veins frequently join immediately on entering the pericardium so that it is simpler to ligate the one structure

The intrapericardial technic is unquestionably simpler and probably safer when the tumor is in close proximity with or adherent to the pericardium. Whether this technic will appreciably increase the incidence of cardiac disorders, especially those of rhythm, will be determined only by experience, but it appears unlikely that this will prove to be of sufficient importance to justify a failure to use the procedure in those cases in which it is especially indicated.

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CHAPTER 34

SEGMENTAL RESECTION OF THE LUNG

LEWIS H. BOSHER, JR.

Segmental resection refers to the excision of individual bronchovascular units of which the pulmonary lobes are composed. Ten such segments are recognized in the right lung; eight to ten in the left. Segments can be further divided into subsegments and occasionally the resection of these latter units is feasible. For detailed consideration of segmental anatomy of the lungs, the reader is referred to the studies of Appleton, Brock, Boyden and associates, and Scannell.

In 1939 Churchill and Belsey described a technic for excision of the lingular segment of the left upper lobe. Subsequently, Blades, Clagett and Deterling, and, particularly, Overholt, made valuable contributions to the technics of segmental resection, and the procedure was eventually applied to almost all the anatomic segments. More recently refinements by other thoracic surgeons have increased the safety and applicability of the method.

At present it is not possible to assign segmental resection its final place in the armamentarium of the thoracic surgeon. The value of the procedure will depend upon the diligence and skill of the individual operator and upon his philosophy regarding the preservation of normal lung tissue. Increasing evidence from physiologic studies emphasizes the disadvantages of overdistention of residual lung tissue. Segmental resection provides an effective means of conserving nondiseased, functioning lung parenchyma while at the same time preventing emphysema of nonresected pulmonary tissue. However, segmental resection is not a technic to be employed by the surgeon who undertakes pulmonary resection infrequently.

The most clearly defined application of segmental resection lies in the treatment of bronchiectasis. In its bilateral form this disease shows a decided tendency to involve the basal segments of the lower lobes, the right middle lobe, and the lingular segment of the left upper lobe. The superior segments of the lower lobes and the remaining segments of the left upper lobe are usually spared. In the interest of conserving the maximum amount of normal lung tissue, segmental resections of the basal groups and of the lingular segment may be carried out. Usually six to twelve months are allowed to elapse after the first operation before the surgeon undertakes the second procedure. The residual superior segments of the lower lobes contribute to respiration and serve to prevent overdistention and emphysema of the upper lobes and middle lobe with attendant disturbances of ventilation and respiration. This beneficial effect assumes more importance in the adult than in the child, since, in the latter, true compensatory hypertrophy of residual lung tissue is doubtless still

possible. Often very little reduction in pulmonary volume results from the excision of diseased, atelectatic segments, since residual normal segments may already have compensated by enlargement.

Excision of individual segments of the basal group is sometimes feasible, but removal of the posterior and lateral basal segments offers special difficulties because of the inaccessibility of their bronchi. The resection of the medial basal segment is more easily accomplished. At times the anterior segment is the only portion of the upper lobe involved. The vascular supply of this segment, especially on the right side, complicates its removal. Few surgeons have expressed a desire to split the middle lobe into segments since the resulting gain is small. The lingular segment presents little technical difficulty, but the surgeon should beware of compromising the arterial supply to the anterior segment during lingulectomy.

Bronchiectasis assumes a segmental distribution and is therefore especially well suited for the application of segmental resection. Only rarely does the inflammatory process traverse the intersegmental plane between diseased and essentially normal segments Unfortunately, this circumstance does not hold true of certain other inflammatory processes for which segmental resection is often employed.

In the treatment of pyogenic lung abscess segmental resection should be restricted to the chronic, well-localized lesion. Dissemination of infection and empyema are likely to result when the procedure is utilized during the acute phase of lung abscess. A subacute abscess, however, may localize rapidly under intensive antibiotic therapy and be rendered suitable for resection by this technic. Pyogenic lung abscess occurs most frequently in the superior segment of the lower lobes and in the axillary divisions of the anterior and posterior segments of the upper lobes. Gratifying results have been obtained in several patients with abscesses in both the superior segment of the lower lobe and the posterior segment of the upper lobe by the performance of a double segmental resection. However, because of the usual unilateral and unilobar distribution of pyogenic lung abscess and because of the frequent association of secondary bronchiectasis one may elect to perform a lobectomy in many patients.

Segmental resection is finding a considerable application in the surgical treatment of pulmonary tuberculosis. Because of the frequently bilateral distribution of this disease segmental resection offers a means of conserving vitally needed lung tissue. The general indications for pulmonary resection in this disease are discussed in a separate section. Although lobectomy has proved of considerable value, the disadvantages of overdistention of residual lung tissue have been obvious. In the presence of a residual, unstable lesion in the ipsilateral lobe, exacerbation readily occurs under such circumstances. Such overdistention can be prevented or minimized by the use of a limited thoracoplasty carried out either before, simultaneously with, or after the lobectomy. The employment of segmental resection should obviate the necessity of thoracoplasty in some instances. Small, stable, localized lesions may be safely left, provided the remaining lung tissue is not subjected to significant overdistention postoperatively. Tuberculous lesions suitable for segmental resection are commonly found in the superior segment of the lower lobe and the apical and posterior segments of the upper lobe. Since Lipiodol may obscure the pulmonary field for some time after its administration, bronchograms are not often available to assist the surgeon in planning his attack. Lateral laminograms are used exten-

sively by some surgeons to identify small lesions and indicate segmental distribution. The availability of antibiotic agents such as streptomycin and para-amino salicylic acid permits the surgeon to traverse diseased tissue without necessarily incurring a tuberculous spread or empyema. Of equal or greater importance, however, are the elimination of all dead space and the avoidance of postoperative atelectasis.

Segmental resection has also been employed in the excision of congenital cysts, benign tumors, and as a method of biopsy.

TECHNIC OF SEGMENTAL RESECTION

The resection of any given segment follows a general pattern. The technical details, however, vary with the anatomy of the region. The operator must keep alert to the many variations of the bronchovascular tree. The bronchial distribution is more constant than either the arterial or venous supply and therefore the bronchus should be used as the primary guide to the segment or subsegment being resected. Preoperative bronchograms, if available, provide a valuable map for the surgeon. Wide exposure through the chest wall is essential in carrying out safely and accurately the details of segmental resection.

The bronchus to the diseased segment is carefully palpated and isolated. In some instances preliminary division of part or all of the arterial supply to the segment is necessary or will greatly facilitate isolation of the bronchus. Arteries should be dissected distally as far as conveniently possible in order to avoid sacrificing anomalous branches to adjacent normal segments (Fig. 388). When the *distribution of an artery is not obvious, where possible its division should be delayed* until the bronchus has been identified and even transected. In the latter instance, traction on the distal divided bronchus assists the operator in arriving at an accurate identification. The advisability of thus delaying ligation of part of the arterial supply will be encountered more frequently during resections on the upper lobe than on the lower. In tuberculous cases dissection is difficult whenever endobronchial disease has led to shortening of the bronchus and to peribronchial scarring. Lymph glands at the bronchial bifurcations may obscure the anatomy. The glands should be dissected away.

Following these preliminary maneuvers, which include identification of the proper bronchus and ligation of part or all of the arterial supply, the venous tributaries are identified in so far as possible at this stage (Fig. 389). Unlike the arteries to pulmonary segments, much of the venous supply enters by way of the *intersegmental plane. Central venous branches can be traced into the segments* also and obviously must be divided. Ligation of the vein at the hilum frequently implies sacrifice of both the central and intersegmental branches, and this mistake should be avoided. If identification of the intersegmental vein is in doubt, ligation of venous tributaries should be delayed until after division of the bronchus.

Prior to division of the bronchus, the lung is allowed to deflate. After occlusion or division of the bronchus (Fig. 390), reinflation of the adjacent lung tissue serves to delineate segments supplied by the divided bronchus. However, all too frequently, collateral ventilation permits partial or complete inflation of the diseased segment also, although somewhat more slowly. The operator must rely on additional measures in defining the limits of this segment. After reinflation the collat-

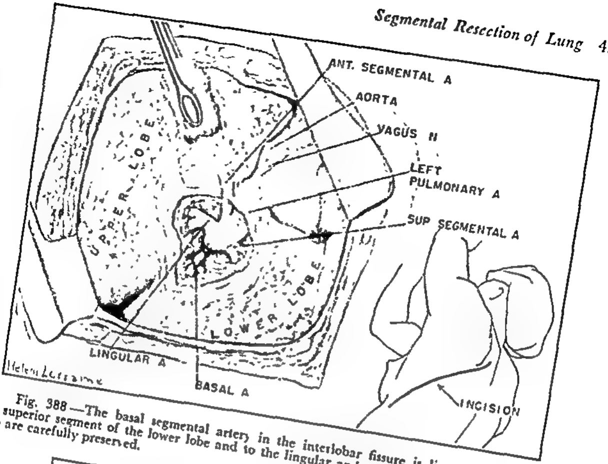

Fig. 388—The basal segmental artery in the interlobar fissure is ligated. Arteries to the superior segment of the lower lobe and to the lingular and anterior segments of the upper lobe are carefully preserved.

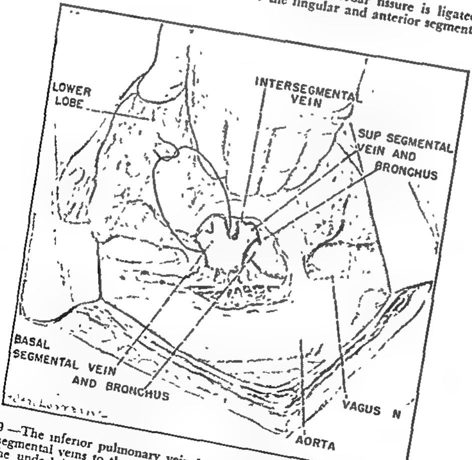

Fig 389—The inferior pulmonary vein is exposed from the posterior aspect. The central and intersegmental veins to the superior segment are accurately identified. They are dissected from the underlying basal bronchus for protection during subsequent division of the bronchus Veins to the basal segments are ligated.

erally ventilated segment may remain inflated as the intact segments are again permitted to collapse. In some instances of long-standing disease, differences in intensity of anthracotic pigmentation assist in identifying the segments. The lingular segment of the left upper lobe and the superior segments of the lower lobes are often marked by notches or partial fissure lines. Injection of a mixture of methylene blue and hydrogen peroxide into the distal divided bronchus has been recommended and may have some value. We have had no personal experience with this technic.

The most reliable and anatomically accurate method of following the intersegmental plane consists in identification and pursuit of the intersegmental vein which lies between adjacent segments.

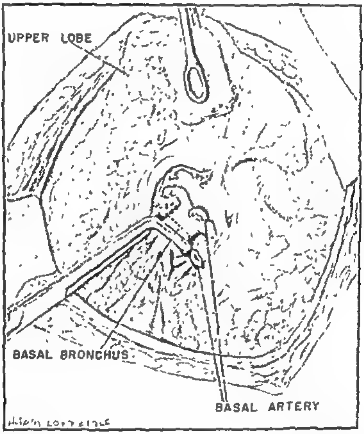

Fig. 390.—The lung is allowed to collapse. The basal bronchus is approached anteriorly, divided, and closed proximally. The distal divided bronchus is secured with a mattress suture ligature.

After division of the bronchus and closure of the proximal stump (Fig. 391), the distal stump is secured with a mattress suture ligature and phenolized. Traction is applied to this stump by means of a clamp and dissection is undertaken in a peripheral direction. The intersegmental vein is identified and followed distally into the parenchyma. The visceral pleura is incised in advance of the intersegmental dissection. Lung tissue is separated by blunt and sharp dissection and for this the fingers are most useful. Frequent irrigation with saline permits dissecting under clear vision at all times By proper tension on adjacent normal segments and on the segment being resected the intersegmental plane is maintained as a relatively flat surface. Simultaneously the segment undergoing excision is triangulated and more accurately defined Dissection is thereby greatly facilitated and damage to

normal segments minimized. Constant traction on the segmental bronchus aids in distinguishing fine venous branches from bronchioles. The direction of ramification likewise guides the surgeon in the identification of these structures. Branches of the intersegmental vein leading into the diseased segment are divided and ligated when further dissection along the true intersegmental plane is otherwise prevented. Failure of the surgeon to recognize and promptly divide these venous branches greatly impedes the progress of the dissection. The intersegmental vein is carefully preserved since its ligation may lead to congestive atelectasis of the adjacent normal segment. Impairment of pulmonary arterial blood supply to residual segments is probably less serious in the immediate postoperative period than is central ligation of intersegmental veins. By following the intersegmental plane accurately, the operator avoids significant air leaks. Small air leaks may be opened by undue traction on venous tributaries entering the adjacent normal segment.

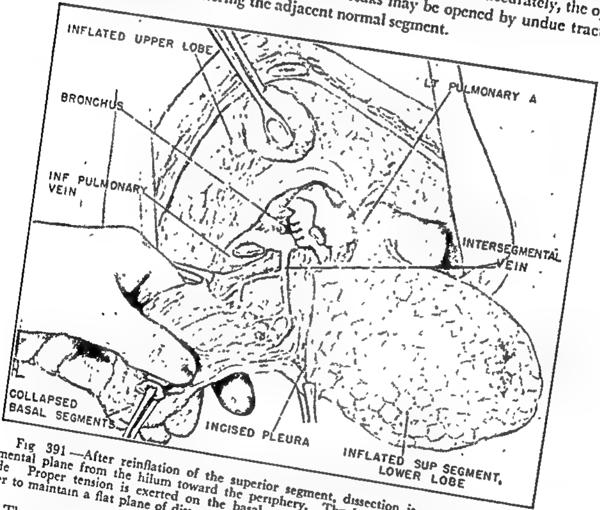

Fig 391 —After reinflation of the superior segment, dissection is carried in the intersegmental plane from the hilum toward the periphery. The intersegmental vein is used as a guide Proper tension is exerted on the basal segments as well as the superior segment in order to maintain a flat plane of dissection

The technic used to resect the lingular segment of the lobe is similar to that just described and is illustrated in Figs. 392, 393, 394, and 395.

Treatment of raw surface remaining after removal of the diseased segment has been the subject of considerable discussion. Resection of the lingular segment leaves a narrow raw surface which may be sutured (Fig. 396), if the surgeon desires. In most instances it is undoubtedly wiser to avoid infolding the raw surface since this leads to distortion of the bronchial tree in the adjacent segments and to restriction of expansion. Extensive air leaks, however, must be avoided by a careful interseg-

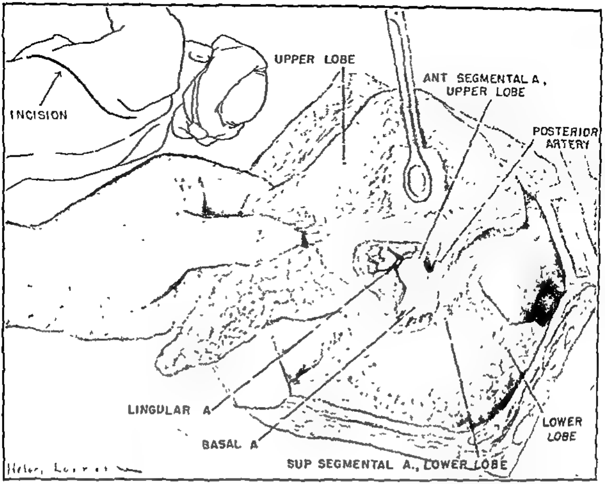

Fig. 392.—Dissection in the fissure discloses the arteries to the lingular segment. In this case the branch to the anterior segment arises in association with the lingular artery—a frequent variation. The lingular arteries, if accurately *identified at this stage*, are divided

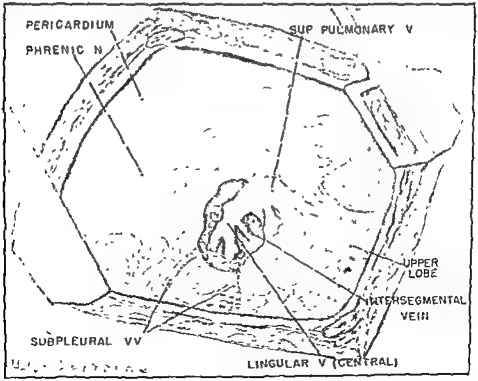

Fig. 393.—Anteriorly at the hilum the superior pulmonary vein is dissected out and the central branches of the l... If the veins are not definitely identified, ligation is dela... The intersegmental vein between the lingular and ant...

mental dissection. Air leaks are especially troublesome when the residual lung tissue is emphysematous and inelastic with little capacity for local contraction or generalized expansion. Pleural grafts have been advocated as a covering for the raw surface, but in general they have not seemed necessary and their effectiveness is open to question. A pleural flap lifted from the diseased segment and hinged on the adjacent normal segment provides perhaps the best method of applying this technic. It would seem advisable to make perforations in the flap to permit release of trapped air. The method is obviously unsuitable when the disease process involves the visceral pleura.

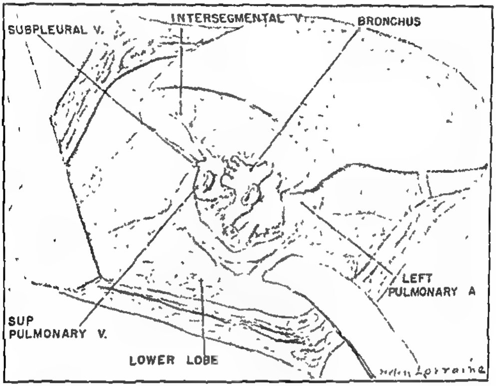

Fig 396—The completed dissection is shown. The raw surface is not closed.

Fewer postoperative complications will be encountered after segmental resection where small amounts of lung tissue have been excised. Air leaks seal off readily as the lung tissue adheres to visceral, parietal, or mediastinal pleura, and when excessive expansion of residual lung tissue is not required. When a large volume of lung tissue has been removed, operative reduction in the size of the thoracic cage may be required to allow the remaining lung tissue to fill the pleural space easily. This problem is of decidedly more significance in tuberculosis where early reexpansion is so important in the prevention of empyema and bronchopleural fistula and where avoidance of overdistention is a requisite for success. Upper lobectomy together with excision of the superior segment of the lower lobe offers an example of segmental resection in which reduction of the thoracic cage is advisable.

Postoperative atelectasis has often been attributed to torsion or kinking of the residual segments. The possibility of such an occurrence does exist, although its frequency has certainly been overemphasized. In order to prevent this complication, adherent fissure lines are left undisturbed and complete fissure lines are partially obliterated by peripheral sutures if torsion seems likely. To permit readjust-

ment as well as uniform and maximum expansion of residual lung tissue, viscero-parietal adhesions are completely divided. The inferior pulmonary ligament is divided after resection of the superior segment of the lower lobe to permit maximum elevation of the basal segments.

The mechanism whereby segmental collateral ventilation or air drift aids in the prevention of segmental atelectasis is now well recognized. After segmental resection, with a single segment remaining in the lobe, this important physiologic safeguard against atelectasis is nonoperative except through an incomplete fissure adjacent to the residual segment. This disturbance in the mechanics of ventilation and expulsion of bronchial secretions may explain some of the poor results reported after total basal segmental resection.

The importance of preserving the activity of the diaphragm cannot be overemphasized. The pumping action of the diaphragm and the maintenance of a sufficiently negative intrapleural pressure are considered essential in securing expansion of residual segments, especially when collateral ventilation is lost. When phrenic paralysis is employed as a means of reducing the volume of the pleural space, it should be performed as a delayed procedure and not simultaneously with the resection.

Following segmental resection intercostal catheters are connected to constant negative suction of approximately 15 cm. of water in order to minimize accumulation of air and fluid in the pleural space. Higher degrees of suction are used intermittently as needed. More than two catheters may be required. Control of air leaks is best accomplished by early sealing of the raw area against pleural surfaces. Should an air pocket become reestablished following withdrawal of the catheters, reintubation of the region is advisable.

Postoperative care assumes great importance. Cough is stimulated frequently, not only to assist in the elimination of bronchial secretions but to enhance the aeration of the lung. Measures to reduce or eliminate postoperative pain are particularly indicated. Tracheobronchial suction, adeptly performed, may be required frequently and should not be delayed until frank atelectasis is recognized. Bronchoscopy is utilized when needed.

Good results in segmental resection depend on careful selection of patients, avoidance of technical errors, and diligent postoperative care. One cannot overemphasize the importance to the surgeon of a detailed knowledge of segmental anatomy and an appreciation of the many bronchovascular variations.

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CHAPTER 35

SURGERY FOR PULMONARY TUBERCULOSIS

FRANK PHILIP COLEMAN

Tuberculosis is a disseminated disease which often involves multiple organs and seldom if ever, is confined to one lung. The ability of the host to overcome the infection is dependent upon the development of immunity to the organism. This immunobiologic response of the body is not too well understood, but it requires serious consideration in the timing of collapse operations, antibiotic administration, and excisional surgery.

To a large extent the pathologic type and behavior of parenchymal disease governs not only the indications for collapse operations or excisional surgery, but also the time for performing these procedures. The pulmonary lesion may be exudative, acute tuberculosis; or the lesion may show a tendency toward fibrosis, productive tuberculosis. Fibrous tissue reaction to pulmonary lesions is indicative of the development of a favorable state of immunity. Progressive loss of weight, elevated pulse rate, daily fever, elevated sedimentation rate, and a large sputum volume usually indicate exudative parenchymatous disease. Serial roentgenograms can be relied upon to determine the activity of a specific lesion. Phrenic nerve paralysis, artificial pneumothorax, pneumoperitoneum, and extrapleural pneumothorax can be employed with a fair chance of success in the predominantly exudative lesions. Thoracoplasty and excisional surgery are reserved chiefly for the fibrocavernous type of disease.

The fundamental therapeutic methods used in the surgical treatment of pulmonary tuberculosis consist of the various collapse operations, external drainage of cavities, and excision of the diseased portion of the lung. Frequently, the lesion does not respond to the clear-cut prescribed therapeutic regimen, and this unpredictable behavior of pulmonary tuberculosis requires, at the time of initial treatment, broad vision as to the possible need for future additional methods of arresting the disease.

OPERATIONS UPON THE PHRENIC NERVE

The phrenic nerve may take origin from the third, fourth, and fifth cervical nerve roots, but the main branch usually comes from the fourth root. It passes distally and medially on the scalenus anticus muscle, and usually lies on the anterior border of this muscle as it passes posterior to the clavicle. While in most individuals the nerve is a single trunk in the lower cervical and thoracic regions, in approximately 40 per cent it receives accessory branches. The accessory branch most commonly encountered takes origin from the fifth cervical nerve and passes

downward on the anterior surface of the upper cords of the brachial plexus with the nerve to the subclavius muscle.

The phrenic is the chief motor nerve to the diaphragm but also carries sensory fibers from the diaphragm and the pericardium. When it is completely divided, paralysis of the corresponding side of the diaphragm is produced, thus reducing the volume and activity of the lung on that side. The exact degree of reduction in volume is difficult to determine and varies in individuals, but there is usually an elevation of the paralyzed side of the diaphragm of from 3 to 5 cm. The reduction in the activity of the lung is probably more important than the change in volume. It is well to bear in mind that paralysis of the phrenic nerve may reduce by 40 per cent the oxygen consumption of the corresponding lung.

The diaphragm can be paralyzed for short periods of time by injecting the phrenic nerve with an anesthetic solution, either Pontocaine or procaine; for longer periods, six to nine months, by crushing the nerve with a hemostat; and permanently by resecting the nerve and its accessory branches or by avulsing it. Transient paralysis of one or both sides of the diaphragm may be indicated in persistent hiccough or in severe pain from diaphragmatic pleurisy. More prolonged paralysis of one side of the diaphragm may be indicated in the treatment of diaphragmatic hernia, either as a palliative procedure to relieve the severe attacks of pain not infrequently associated with this condition, or to aid in the repair of the hernia. Permanent interruption of the ipsilateral diaphragm may be indicated during pneumonectomy or following lower lobe lobectomy for tuberculosis. In the former it aids in obliterating the pleural cavity, while in the latter it is thought to prevent reactivation of tuberculous foci in the remaining lobe or lobes.

Temporary paralysis of the diaphragm is most frequently used in the treatment of pulmonary tuberculosis. It may be used as a separate procedure or as an auxiliary operation to some other collapse measure. As a separate procedure it finds its chief usefulness in the treatment of minimal lesions anywhere in the lung or in unilateral lesions which are so early or so limited in extent that collapse of the lung by artificial pneumothorax does not seem justifiable. Occasionally in extensive unilateral disease where pneumothorax or pneumoperitoneum are impossible, paralysis of the ipsilateral diaphragm may lead to stabilization of the lesion and permit a subsequent thoracoplasty. This operation alone has very little therapeutic value in the treatment of fibrocavernous tuberculosis. At the present time phrenic nerve crush is used extensively as an auxiliary operation to pneumoperitoneum. It also may be used as an auxiliary operation to pneumothorax or thoracoplasty. There is seldom an indication for permanent paralysis of the diaphragm in the treatment of pulmonary tuberculosis other than the ipsilateral performance of this procedure in total pneumonectomy and lower lobe lobectomy for tuberculosis.

The technic of phrenic nerve operations is simple. The patient is placed in the dorsal recumbent position with the shoulders slightly elevated and the head extended and turned to the opposite side. Anesthesia is produced by the local injection of 1 per cent procaine solution, precautions being taken to avoid injecting the solution into a blood vessel, or the vagus nerve. The solution is injected intradermally along the proposed line of incision, which should be placed in a cervical crease about 4 cm above the clavicle. The subcutaneous tissue is next injected and then the deep tissues are infiltrated, the tip of the operator's finger being placed on the scalenus anticus muscle as a guide. When only a very transient paralysis of

the diaphragm is desired, the procaine solution may be injected through an intradermal wheal, which is made directly over the scalenus anticus muscle about 5 cm. above the clavicle.

The incision is started at the posterior border of the sternocleidomastoid muscle and extended backward for a distance of about 3 cm. (Fig. 397). It is carried through the skin, subcutaneous tissue, platysma, and the deep cervical fascia and exposes the posterior margin of the sternocleidomastoid muscle. The external jugular vein is frequently encountered and is retracted posteriorly.

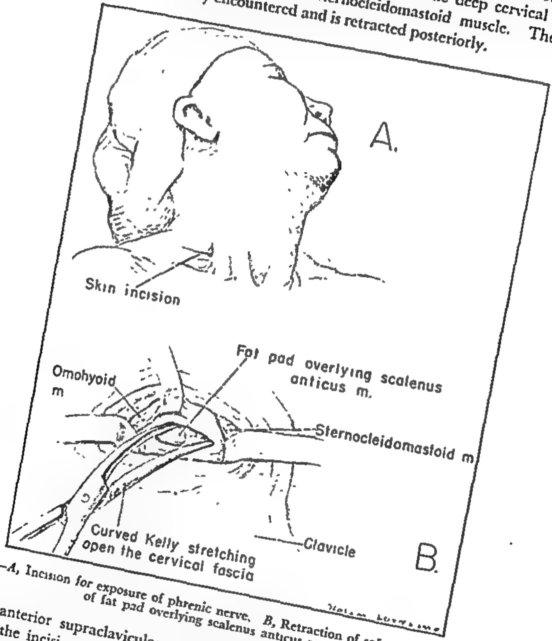

Fig. 397.—*A*, Incision for exposure of phrenic nerve. *B*, Retraction of soft tissue and exposure of fat pad overlying scalenus anticus muscle

The anterior supraclavicular nerve must also be preserved if it lies in the course of the incision. After division of the deep cervical fascia, the loose tissue beneath the fascia is separated by inserting a hemostat and carefully opening it. The sternocleidomastoid muscle is retracted anteriorly and the soft tissue posteriorly, exposing a clump of fatty tissue which is an excellent guide to the proper plane for location of the phrenic nerve. The omohyoid muscle may be exposed under the fascia; if so, it is retracted upward and the scalenus anticus muscle is identified by inserting the tip of the index finger through the opening in the fascia. The scalenus

anticus muscle is exposed by careful blunt dissection under direct vision, with the soft tissue retracted by blunt right angle retractors. Special care should be taken to avoid injuring the superficial cervical artery. On the left side, the thoracic duct must be avoided, but there should be little danger of injury to this structure if the dissection is carried out at the proper level. The nerve is usually readily recognized as it crosses the muscle obliquely, from above downward and forward. It is

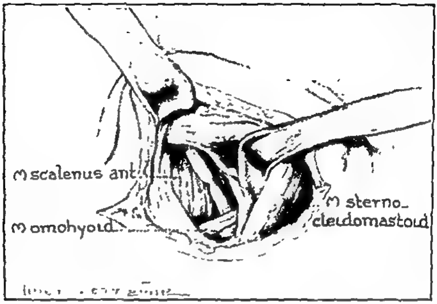

Fig. 398.—Method for producing temporary paralysis of the diaphragm by crushing the phrenic nerve. The nerve may be exposed either above or below the omohyoid muscle.

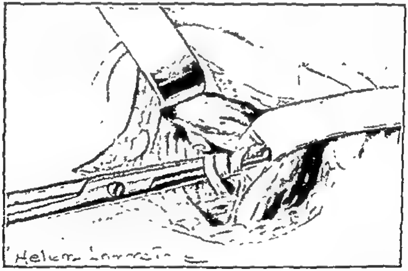

Fig 399.—Method of avulsing the phrenic nerve. Special clamps are available for this procedure but are not necessary

exposed by careful dissection for 2 cm. and injected with procaine solution through a fine needle in the upper portion of the field. After waiting a sufficient length of time to allow the anesthetic to take effect, the nerve is positively identified by stimulating it below the point of injection, with the resulting characteristic contraction of the diaphragm if it is the phrenic.

If only a temporary paralysis of the diaphragm is desired, the main phrenic trunk is thoroughly crushed with a small hemostat (Fig. 398). A careful search

should be made for accessory branches to the phrenic nerve which are resected for a distance of 1 cm. unless the accessory nerve is large and constitutes the major part of the nerve supply to the diaphragm. Since the accessory phrenic nerve usually arises from the fifth root of the brachial plexus along with the nerve to the subclavius muscle, the nerve to the subclavius should be resected at the time of crushing the phrenic nerve. Permanent paralysis may be obtained by searching out all accessory branches, including the nerve to the subclavius muscle, and resecting them along with the main nerve, or by avulsing the main nerve. If the nerve is to be avulsed, it is divided in the upper portion of the field, the distal segment is grasped by a clamp and gradually drawn out by winding the nerve over the clamp (Fig. 399). Special clamps with shoulders have been devised for this purpose to prevent the nerve from slipping off the end, but any strong straight hemostatic clamp is adequate. Traction should be continuous but not too forcible and should be directed cephalad to avoid injury to vessels overlying the nerve. If the nerve is adherent or if traction on it causes severe pain or cardiac irregularity, avulsion should be abandoned and 2 to 3 cm. of the nerve resected. The wound is closed as illustrated (Fig. 400).

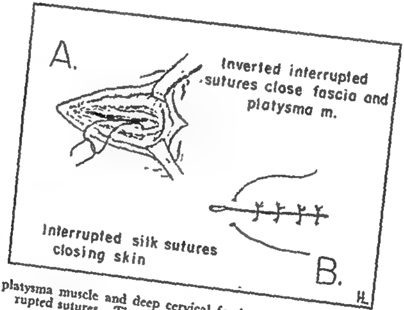

Fig 400.—The platysma muscle and deep cervical fascia are approximated by inverted interrupted sutures. The skin is closed by interrupted sutures.

Avulsion of the phrenic nerve carries a greater danger than the other procedures mentioned. The tendency at the present time is to employ temporary paralysis of the diaphragm, especially in the treatment of pulmonary tuberculosis.

THERAPEUTIC PNEUMOTHORAX

Artificial pneumothorax is one of the most commonly used and one of the most valuable methods of producing therapeutic pulmonary collapse, if it can be continued without complications. It has a number of advantages over the other procedures. The most important of these are the simplicity of technic, the degree of collapse obtainable, and the fact that reexpansion of the lung is possible when collapse is no longer necessary.

The indications for artificial pneumothorax are at the present time under severe scrutiny. The high incidence of complications attending its application to

acute exudative disease has led some clinicians to adopt pneumoperitoneum as a substitute. Preliminary treatment of acute exudative disease for several weeks with streptomycin will likely reduce the incidence of complications attending pneumothorax. In general, artificial pneumothorax is applicable to cavitary and progressive disease. If the exudative component of the lesion is predominant and attended by severe constitutional symptoms of toxicity, it is safer to resort to pneumoperitoneum or to administer a course of streptomycin prior to the induction of pneumothorax. Pneumothorax is also indicated in progressive minimal disease and in the slowly progressive indolent lesion. When pneumoperitoneum fails to control the cavitary lesion but successfully controls the exudative lesion, it may be used as a supplementary definitive collapse measure. Positive pressure cavities, pneumonic lesions, and tuberculous tracheobronchitis usually may be considered as contraindications to artificial pneumothorax. Excellent results can be obtained with pneumothorax in both unilateral and bilateral disease if all the factors influencing the indications for its use are carefully appraised.

The site of election for the injection of air into the pleural cavity will depend on a number of factors, the most important being the location of the principal pulmonary lesion. In general, it is wise to make the injection at a point distant from the area of the most active or the most superficial inflammatory lesion, because the two layers of pleura are more likely to be adherent over such areas. If there is no contraindication, the area between the midaxillary and posterior axillary lines at the level of the sixth or seventh intercostal space is chosen, because the lung is the only important underlying structure and the intercostal spaces and ribs in this area are not covered by heavy muscles. An eighteen or nineteen gauge needle with a short bevel and a rather blunt point may be used. Special needles with side arms, stylets, and lateral openings have been devised and may facilitate the procedure but are not necessary. A standard pneumothorax machine, equipped with a water manometer, should be used. A glass connecting tube which has been lightly packed with cotton and then dry sterilized is used to filter the air.

The skin and deeper structures, including the pleura, should be carefully anesthetized with 1 per cent procaine solution and the skin then punctured with a sharp-pointed knife. The needle is connected with the manometer and inserted so that it will enter close to the upper margin of a rib. After passing through the deep fascia, it will encounter no other dense structure until the endothoracic fascia and pleura are reached. These structures give an increased resistance and the needle should be inserted through them with special care, while the operator observes the manometer for the respiratory oscillations which indicate that the pleural cavity has been entered. A gradually increasing pressure usually means that the needle has been inserted into a vessel, and it should be withdrawn immediately. A moderate fluctuation from positive to negative indicates that the needle has entered the lung, so it should be withdrawn When the characteristic oscillations are obtained, the air injection may be begun After 75 to 100 c.c. of air have entered, the intrapleural pressure should again be determined. A change from negative to positive pressure following the injection of a small amount of air usually indicates that the needle has entered a small pleural pocket, so another area should be tried. If only a slight change in the intrapleural pressure occurs, the injection should be continued until an additional 100 c.c. of air have been introduced. No

more than 300 c.c. of air should be permitted to enter the pleural cavity at the time of initial pneumothorax except in pulmonary hemorrhage when 700 to 800 c.c. may be given at one time, but such rapid collapse is usually undesirable. The injections should be made every two or three days at first and then less frequently as the desired degree of collapse is obtained and the rate of absorption decreases. The pressure necessary to obtain an adequate collapse will vary in different individuals; but, as a rule, sufficient collapse is obtained with a negative intrapleural pressure on inspiration and expiration.

It is desirable at the initial injection and in the presence of numerous adhesions to have the patient's head lower than the body to avoid the danger of cerebral air embolism. Under such circumstances it may be wise to use carbon dioxide or oxygen in place of air as these gases are absorbed rapidly if injected accidentally into the circulation. Under ordinary conditions air is as satisfactory as any of the gases.

Careful aseptic technic should, of course, be followed throughout the procedure.

Injury to the underlying lung during the introduction of air by the needle or by the pull of an isolated adhesion may convert a therapeutic pneumothorax into an accidental one, with the result that the lung may be too rapidly and too completely collapsed. It may even happen that the tear leads into a small bronchus or a superficial cavity which communicates with a bronchus, thus producing a valvular or tension pneumothorax. The treatment of this condition has been described elsewhere.

A large percentage of patients receiving pneumothorax develop a small pleural effusion at one time or another, and in a small percentage a massive effusion results. An occasional patient develops either a tuberculous or a mixed empyema. Small effusions which do not rise above the level of the diaphragm are of little consequence unless attended by fever and require no special treatment. If there is a large amount of exudate, the fluid is removed in order to prevent fibrothorax which may lead to obliterative pleuritis or may prevent later reexpansion of the lung. Serious consideration should be given to the abandonment of pneumothorax when there is massive effusion associated with persistent fever. The treatment of empyema has been discussed in a previous chapter.

Unfortunately, a rather high percentage of patients in whom pneumothorax is indicated cannot be given an adequate collapse because of the presence of adhesions between the parietal and visceral layers of pleura and, as a rule, the densest adhesions occur over the most diseased portion of the lung. If it were not for the occurrence of adhesions, the more radical procedures for producing pulmonary collapse would rarely be necessary. Fortunately, methods have been developed which permit the division of certain types of pleural adhesions and thereby permit the continuance of the pneumothorax. The most important of these methods is termed closed internal pneumonolysis or the division of pleural adhesions under thoracoscopic control.

CLOSED INTERNAL PNEUMONOLYSIS

This procedure, which was first described by Jacobaeus in 1913, was not adopted immediately in this country. However, with improvement in the instruments as well as in the technic of the operation, it has become a safe and valuable

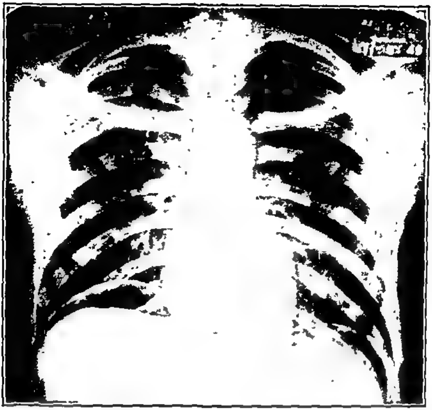

Fig. 401.—Moderately advanced pulmonary tuberculosis, upper lobe, right lung, with persistent cavity following pneumoperitoneum of six months' duration and a ninety-day course of streptomycin.

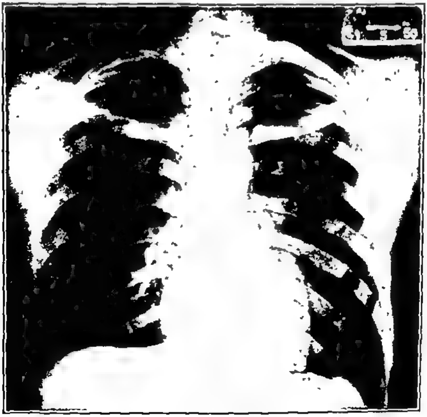

Fig 402 —Same case as Fig 401, showing cavity held open by adhesions two months following the institution of artificial pneumothorax.

aid in the pneumothorax treatment of pulmonary tuberculosis. In a series of 451 patients with artificial pneumothorax referred for division of adhesions, 36 or 8 per cent showed the lung to be so adherent to the chest wall that pneumothorax was abandoned without consideration of even a thoracoscopy. Closed intrapleural pneumonolysis was attempted in 415 cases. Division of the adhesions was complete in 48 per cent, incomplete in 38.8 per cent, and in 13.2 per cent the adhesions were found to be unsuitable for division. Observation over a period of five months revealed no serious postoperative complications other than the development of empyema in 4.5 per cent of the patients. The results were highly satisfactory in over 70 per cent of the patients where division of the adhesions was either partial or complete.

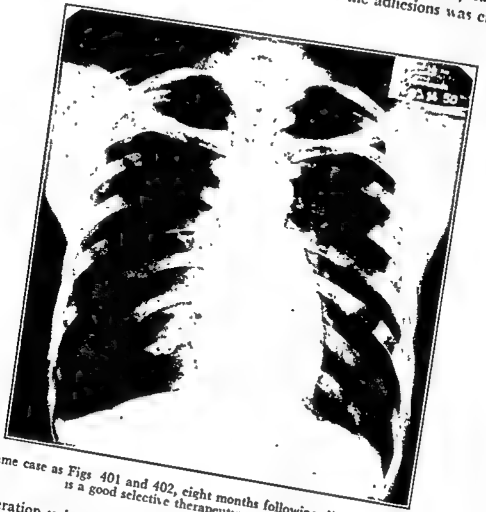

Fig 403 —Same case as Figs 401 and 402, eight months following division of adhesions This is a good selective therapeutic pneumothorax.

The operation is indicated when the collapse of a diseased area of lung, especially a cavity, is prevented by adhesions (Figs. 401-403). The suitability of the adhesions for division cannot be determined preoperatively by roentgenograms and fluoroscopy, although valuable information may be obtained by such preoperative studies It is necessary that the adhesions be localized, be string-, band-, web-, or cord-like in character, and of sufficient length to give adequate space for the necessary manipulation and for good vision. Sheetlike adhesions or fusion of the two layers of pleura over a broad area, tuberculous pleuritis, acute febrile pleurisy with effusion, dense adhesions over a large peripherally placed cavity, and the presence of a positive pressure cavity which shows an increase in size under pneumothorax

Fluoroscopic examination and stereoscopic roentgenograms may indicate the most suitable place for introduction of the trocar. In most cases the first cannula has been introduced through the third intercostal space just anterior to the anterior axillary line, and the second cannula for the cautery has been introduced through the fifth to the seventh intercostal space in the posterior axillary line. The position of the adhesions may require introduction of the cannula medial to the vertebral border of the scapula, but this region is avoided if possible, because the narrow intercostal space limits the maneuverability of either the thoracoscope or the cautery. The cannulas may be used interchangeably for either the cautery or the thoracoscope.

It is always advisable to inspect the equipment carefully before starting such an operation. It should be determined that additional sterile light bulbs are available, that the lens is clear, and that the cautery is functioning properly.

The area chosen for puncture is well anesthetized with 1 per cent procaine solution. The pleura may best be anesthetized by inserting the needle into the pneumothorax and carefully withdrawing it to a level where air cannot be aspirated. At this point, 5 to 10 c.c. of 1 per cent procaine solution are deposited in the subpleural plane. If the division of an adhesion causes undue discomfort, procaine solution may be injected under thoracoscopic guidance into the chest wall over the point of attachment of the adhesion. A transverse incision about 2 cm. in length is made through the skin, and the trocar and cannula are inserted immediately above the upper border of a rib. As soon as the pleura is penetrated, the trocar is partly withdrawn and the cannula is passed into the pleural cavity for about 2.5 cm. The trocar is then completely withdrawn and the observation telescope is inserted with the lens directed upward (toward the lateral chest wall) to avoid having the lens and the light bulb obscured by blood. The pleural cavity is carefully inspected to determine its condition and the adhesions are examined with regard to number, location, shape, size, and vascularity. If an unsuspected tuberculous pleuritis is encountered, *the operation is terminated at this stage. If it is decided that the adhesions are* suitable for division, the area at which the cautery is to be inserted is anesthetized, and the second cannula is introduced into the pleural cavity. The pleura may be inspected with the thoracoscope, through the second cannula, in order to gain added information. The presence of peripheral or tension cavities should be kept in mind during the procedure, for separation of the adhesions may be followed by rupture of such a cavity into the pleural space.

The position of the patient is changed frequently during the operation so that the weight of the lung will put the adhesions on stretch during their division. The entire procedure should be carried out under thoracoscopic control and the current should never be turned on unless the cautery tip can be clearly visualized. The operator can best control the current by a foot switch. *If* the galvanocautery is employed, it is best to use only enough current to produce a dull red glow. The flat surface of the cautery is applied to string and cord adhesions near their parietal attachments. The adhesions are heated slowly, thus producing a narrow zone of coagulation. The edge of the cautery may then be used to cut through the coagulated zone without danger of hemorrhage. Short adhesions and adhesions which may contain lung tissue are freed from the chest wall by Carter's method (Fig. 406). They should not be divided by the cautery. The parietal pleura and endothoracic fascia are incised near the attachment of the adhesion to the thoracic

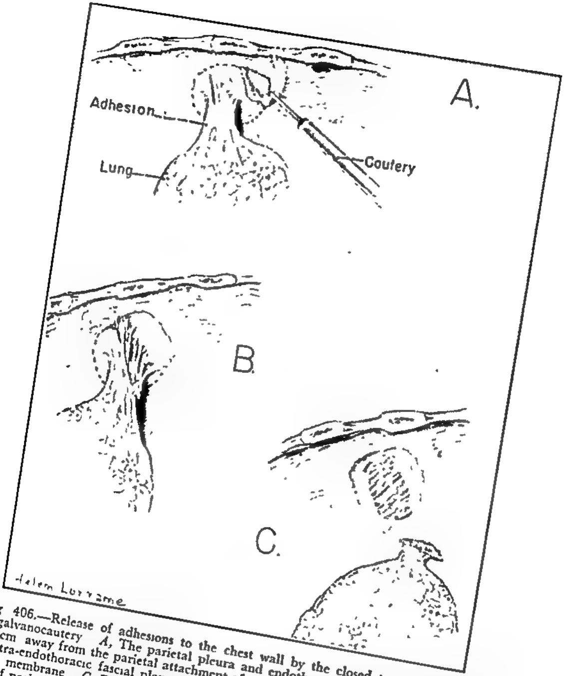

Fig 406.—Release of adhesions to the chest wall by the closed type of pneumonolysis using a galvanocautery *A*, The parietal pleura and endothoracic fascia are divided approximately 1 cm away from the parietal attachment of the adhesion. *B*, The adhesion is separated in the extra-endothoracic fascial plane, leaving exposed the internal intercostal muscle or the intercostal membrane *C*, Division of adhesion is complete, leaving an area on the chest wall denuded of parietal pleura three times the diameter of the released adhesion.

wall and the lung is released from its anchorage. By carefully cutting in the extrafascial plane with the hot cautery it is possible to free the lung safely over large areas. Frequently the intercostal muscles can be seen through the remaining thin layer of fascia. If the lung is suspended by short adhesions to the subclavian or innominate vessels, it is best to abandon the procedure. If the adhesions are very extensive, they should be divided in stages, for if too much is done at one time the patient becomes exhausted and there is a more severe reaction. If a partially divided adhesion must be left adjacent to a peripheral cavity, it is better to abandon the pneumothorax. If there is no cavity adjacent to a partially divided adhesion, the pneumothorax should be continued and an attempt should be made later to complete the division.

After completion of the pneumonolysis it is well to inspect the sites where the cannulas penetrate the pleura. If bleeding is observed at either of these sites, the cannula should be removed and observation of the site continued, while pressure is applied over the area. If massage of the chest wall does not arrest the hemorrhage, it may be necessary to place pericostal sutures of catgut about the corresponding ribs and intercostal vessels. Injury to the intercostal vessels by the trocar is the most likely cause of serious postoperative intrapleural hemorrhage following pneumonolysis *After removal of one cannula, the intrapleural pressure should be* adjusted so that it is negative, both on inspiration and expiration, before removal of the second cannula The wounds are closed by interrupted sutures of cotton and a light dressing is applied The patient is returned to his bed and instructed to lie on the good side and codeine is given in sufficient doses to control cough. The development of increased intrapulmonary pressure, as pointed out by Brantigan, is the most common cause of postoperative subcutaneous emphysema. Excessive cough and check-valve obstruction of the bronchi by either endobronchial lesions or bronchiospasm are responsible for the increased intrapulmonary pressure. Brantigan recommends that ephedrine in oil be given to those patients who show subcutaneous emphysema. The patient is carefully observed, especially during the first two weeks. Persistence of fever and the development of massive effusion during this period should lead to serious consideration of abandonment of the pneumothorax.

OPEN INTERNAL PNEUMONOLYSIS

The open operation for the division of pleural adhesions is much less satisfactory than the closed operation and is infrequently justifiable. It is not indicated for adhesions too extensive to be divided by the closed method, especially when there is a fusion of the two pleural surfaces. Posterior extrapleural thoracoplasty is usually preferable under these conditions. However, under certain circumstances where closed intrapleural pneumonolysis has been tried and has failed and where active disease in the contralateral lung contraindicates thoracoplasty and has not responded to pneumoperitoneum, open intrapleural pneumonolysis may be the procedure of choice. Very heavy or vascular adhesions can best be divided by resecting a small segment of an adjacent rib and incising the posterior periosteum and pleura (Fig. 407) The adhesion is then doubly ligated and divided

The posterior approach as recommended by Alexander has many advantages, and usually the fourth rib is subperiosteally resected for a distance of 5 to 10 cm.,

depending upon the location and extent of adhesions. Adhesions containing lung tissue may be freed by the method described by Carter in 1931. An incision is made through the pleura, circumscribing the area of attachment of the adhesions, and that portion of the pleura is dissected off. The margins of the pleura attached to the end of the adhesion are then carefully approximated so that there is no exposed lung tissue. As pointed out by Carter, it is desirable to resect a rib adjacent to, but not directly over, the adhesion; otherwise the parietal pleura cannot be closed and extensive subcutaneous emphysema may result.

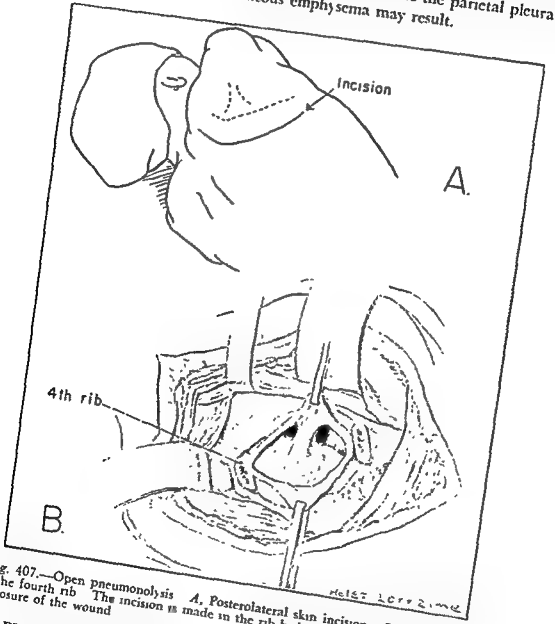

Fig. 407.—Open pneumonolysis *A*, Posterolateral skin incision. *B*, Subperiosteal resection of the fourth rib The incision is made in the rib bed so that the periosteum may be used in the closure of the wound

EXTRAPLEURAL PNEUMOTHORAX

Tuffier performed the first extrapleural pneumothorax in 1891. Following a report by Graf in 1935 and one somewhat later by Schmidt, this method of collapse was enthusiastically adopted by many clinics outside of Germany. The procedure was widely used in this country and many operations were performed before the inherent danger of complications was recognized and before sufficient experience

had been gained in the selection of cases. The high incidence of complications and the use of pneumoperitoneum in the treatment of active lesions when thoracoplasty is contraindicated have resulted in the infrequent use of extrapleural pneumothorax.

It would appear that extrapleural pneumothorax has a number of advantages over thoracoplasty, some of which are obvious to laymen as well as to physicians. This is particularly true of the lack of deformity following extrapleural pneumothorax, as contrasted with the noticeable deformity which often follows thoracoplasty. Extrapleural pneumothorax is less shocking and is technically easier to perform than thoracoplasty. A more selective collapse may be obtained by extrapleural pneumothorax, a distinct advantage.

The indications for extrapleural pneumothorax are not sharply defined Its use is not recommended in those patients with either unilateral or bilateral disease where activity or progression of the lesion contraindicates thoracoplasty, especially when pneumoperitoneum has not been given an adequate trial. Extrapleural pneumothorax is indicated in patients with unilateral and bilateral, apical or subapical, disease when adhesions do not permit intrapleural pneumothorax and when the lesion fails to respond satisfactorily to pneumoperitoneum and thoracoplasty is contraindicated because of activity of the lesion. It may be used for the collapse of one or both apices when age, low vital capacity, or disease in the other lung contraindicates thoracoplasty. Extrapleural pneumothorax may occasionally be employed in conjunction with contralateral thoracoplasty or intrapleural pneumothorax. Bilateral extrapleural pneumothorax may be considered in children with the adult type of parenchymal lesion requiring a major collapse procedure.

Although extrapleural pneumothorax has a number of obvious advantages, it also has dangers, some of them unfortunately not so obvious. Among the more serious complications are hemorrhage or infection in the extrapleural space. The infection may be either pyogenic or tuberculous. Stripping the pleura from the chest wall over an area sufficient to collapse the diseased portion of the lung may destroy the blood supply to the superficial portion of a thin-walled cavity. Necrosis of the unsupported wall of the cavity with rupture into the large extrapleural space causes a fulminating infection. Positive pressure cavities, large and peripherally located cavities, and ulcerative tuberculous bronchitis contraindicate extrapleural pneumothorax. In a series of forty-two operations performed upon forty patients during the past twelve years, six, or 15 per cent, developed either early or late extrapleural empyema, and postoperative hemorrhage occurred in three additional patients Of the three patients with hemorrhage the space was preserved in two by immediate evacuation of the hematoma and the third was later subjected to an extrapleural thoracoplasty The rupture of a cavity into the extrapleural space was not a complication in this series and there were no deaths

In recent excellent and comprehensive papers by Head and Moen and by Smart, Sampson, and Childress, the late results of extrapleural pneumothorax show that satisfactory results can be accomplished with this operation in approximately 75 per cent of cases.

The technic of the operation is not so difficult, but it must be carried out with meticulous care to prevent hemorrhage and infection. Even with the greatest care and the administration of antibiotics both before and after operation, there apparently is no way of avoiding the development of empyema in an appreciable number

of cases. Careful attention to hemostasis usually will prevent postoperative hemorrhage. Antibiotics are administered daily for one week preoperatively and for a period of two weeks after the operation.

The operation may be performed under local and intercostal nerve block anesthesia or under general anesthesia. If the former is employed, blocking of the upper eight intercostal nerves with 1 per cent procaine solution is necessary. We have used local anesthesia in approximately one-third of our cases and have used sponges saturated with procaine for the mediastinal dissection as suggested by Coryllos. The chief objection to the use of local anesthesia is that separation of the mediastinal pleura often causes paroxysmal coughing which interferes with the operation. An incision is made, midway between the spinous processes of the vertebral column and vertebral border of the scapula, extending from the level of the

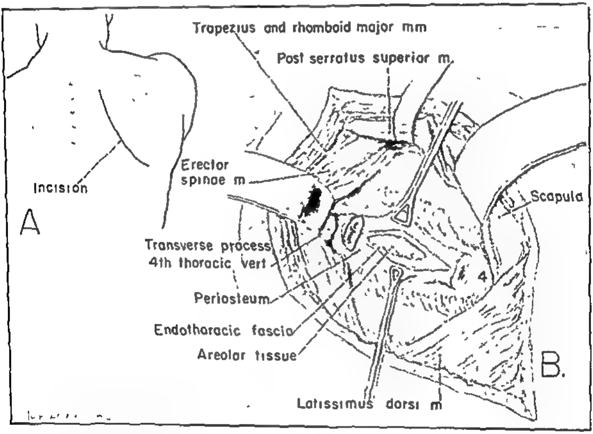

Fig. 408.—Extrapleur... pproach to extrapleural plane. The areolar tissue ... and the parietal pleura serves as an excellent landn... the extrapleural space.

second thoracic spinous process to just below the inferior angle of the scapula (Fig. 408, *A*). The trapezius and rhomboid muscles are divided in the line of the incision and the scapula is retracted laterally and anteriorly. The posterior superior serratus muscle is carefully separated from its insertion onto the fourth and fifth ribs and turned upward. The erector spinae muscles are carefully mobilized so that they can be used later in securing an airtight closure of the wound. These muscles are retracted toward the midline. The fourth rib is resected subperiosteally, starting at the tip of the transverse process and extending laterally for 10 cm. The periosteum is carefully elevated so that it can be used for closure. The periosteal bed is incised longitudinally and the endothoracic fascia, which may be extremely thin

in this area, is also divided. The areolar tissue which lies between the endotho fascia and parietal pleura serves as an excellent guide to the proper plane fo velopment of the extrapleural space (Fig. 408, *B*). The cut edges of the int periosteum and endothoracic fascia are grasped by small tissue forceps or clamps and retracted away from the pleura, which is carefully separated fron fascia. This part of the dissection should be done with a scalpel, supplemente blunt dissection. After the dissection has been carried a few centimeters away the line of the incision, a finger is inserted and the stripping is continued unti limits of the fingers are reached. The field is illuminated by a small, lighte tractor which also serves to keep the lung depressed while the dissection is ca out, under direct vision, by means of a small sponge on a curved clamp. Pre is directed against the chest wall rather than against the lung. This is espe important when dissection is being done over thin-walled cavities. Ordinarily most adherent areas are found posteromedially and at the pleural dome, but dense adhesions are encountered over cavities. When the adhesions over a c are dense, it is advisable to carry the separation of the pleura around the cavit it will frequently be found that the dissection may be accomplished more e when the approach is made from another direction. If this part of the disse is still difficult, it is better either to discontinue the operation or to follow the gestion made by Jones and Dolley and establish an extrafascial plane of clea until the difficult area has been separated. The fascia may then be divided ar this area and the original subfascial line of cleavage again entered. Carele clumsy manipulation may rupture a peripheral cavity which communicates the inner layer of the chest wall. Satisfactory suture of the tear is not possible a fistula will develop later. This accident requires an immediate extraple thoracoplasty for tamponade of the tear into the cavity. Bleeding from small sels passing between the superficial structures and the pleura usually can be trolled by pressure, but if this is not possible they may be ligated or close silver clips. If local anesthesia or a noninflammable anesthetic is being used, bl ing may be controlled by coagulation.

The extent of the dissection should be decided mainly on the basis of the l tion and extent of the lesion In general, it is advisable to do a more exter pleurolysis than appears to be necessary, as there is a tendency for the extraple cavity to shrink in size during the first few weeks. It has been our practic separate the pleura to the level of the third rib anteriorly, the fifth rib later and the seventh rib posteriorly, and to the level of the azygos vein on the right the midaortic arch on the left This permits equal relaxation of the lung in directions The azygos and innominate veins on the right and the subclavian sels on the left must be identified and protected. After the pleurolysis has b completed, the extrapleural cavity is thoroughly flushed out with warm saline s tion and inspected for bleeding Five hundred cubic centimeters of physiol saline solution, 300,000 units of penicillin, and 1 Gm. of streptomycin are place the extrapleural space prior to closure of the wound. The closure should be m as nearly airtight as possible The periosteum is carefully approximated by in rupted sutures of fine cotton on an atraumatic needle and the intercostal mus are brought together over the periosteal suture line by the same type of sutu In order to secure satisfactory approximation of these structures, they are rela by separating the posterior periosteum from the adjacent rib borders. The sa

spinalis muscles are sutured over the medial end of the incision and the posterior superior serratus muscle is used to complete the closure in this plane. The trapezius and rhomboid muscles are then approximated by a running suture of chromic No. 1 catgut and the subcutaneous tissue and skin are closed with interrupted sutures of No. 60 cotton. The pressure in the extrapleural space is left at atmospheric level, usually plus 8 and minus 8 cm. of water pressure.

The extrapleural pneumothorax cavity requires careful observation during the first postoperative week. Frequent aspiration, irrigation, and air replacement are necessary. Twelve hours following the operation the extrapleural pneumothorax pressures are checked, and if the air space is adequate no further interference is necessary. On the first postoperative day the serosanguineous fluid is aspirated and air is introduced, leaving the pressure atmospheric or slightly positive. The space is checked daily thereafter, and penicillin and streptomycin are injected into the extrapleural space at the time the fluid is removed. Codeine is administered in sufficient dosage to control excessive cough. After a period of ten days, a positive pressure of from 20 to 30 c.c. of water is established. Small hemorrhages into the extrapleural space are managed by aspiration and irrigation. The persistence of fluid in the extrapleural space should arouse suspicion of an empyema; however, it is not uncommon to see small effusions develop in those cases where the interval between refills is extended to one month or more.

The development of an extrapleural empyema is not accompanied by the systemic reactions usually observed in intrapleural empyema. Empyema of the extrapleural space most often responds satisfactorily to aspiration, irrigation, chemotherapy, and antibiotics. If such conservative measures fail, a classical posterolateral extrapleural thoracoplasty should be carried out to obliterate the space. The extrapleural space is maintained by air refills rather than extrapleural oleothorax. The latter has been recommended for tuberculous extrapleural empyemas to forestall obliteration of the extrapleural space. It is recognized that extrapleural pneumothorax generally results in permanent collapse and the chance of this is increased by filling the extrapleural space with Gomenol oil.

THORACOPLASTY

Thoracoplasty is indicated for those patients with predominantly productive and unilateral cavernous tuberculosis where pneumothorax and other conservative collapse measures have failed to control the disease. The exudative component of the lesion should be regressive or stationary in character without evidence of recent exacerbation. The cardiac and respiratory reserve must be adequate and the general condition of the patient must be equal to withstanding this major surgical operation. Progressive gain in weight, stable pulse, declining sedimentation rate, and absence of fever over a period of several months are clinical indications of stability of the lesion. The indications for thoracoplasty in the treatment of tuberculous empyema have been considered in a previous chapter.

Approximately 10 per cent of all patients admitted to sanatoria require thoracoplasty. Thus, a relatively large number of patients are subjected to this method of permanent collapse. The effectiveness and safety of thoracoplasty are well illustrated in a series of 420 cases in which the patient mortality rate was less than 4 per cent in six months and cavity closure, with consistently negative sputum, was

accomplished in approximately 80 per cent of the patients. Late follow-up studies show that few patients with thoracoplasty have a relapse or recrudescence of the disease. Such satisfactory results have generally led to the exclusion of other collapse measures and pulmonary resection in those patients who are suitable candidates for thoracoplasty.

The original Brauer-Friedrich thoracoplasty for tuberculosis consisted of the removal of long segments of the second to the ninth ribs with the periosteum and intercostal muscles in one stage. The operation produced severe shock and carried a high mortality. Brauer later decided to leave the periosteum and intercostal muscles in order to permit regeneration of the ribs and fixation of the chest wall in the collapsed position. This operation still had an unduly high mortality, but yielded a rather large percentage of cures in those patients who survived it. Wilms and Sauerbruch developed the operation of paravertebral thoracoplasty independently of each other. They both resected short posterior segments of the ribs at first and later resected up to 10 cm. or more of the lower ribs and somewhat shorter segments of the upper ribs.

The modern operation of paravertebral extrapleural thoracoplasty is based upon the Wilms-Sauerbruch technic and differs from it mainly in that the present tendency is to remove very long segments from the upper ribs and relatively shorter segments from the lower ribs. Originally, the operation frequently was done in one stage, and when divided into two stages the lower ribs were resected first. The upper ribs are now resected first, and division of the procedure into multiple stages, as first practiced by John Alexander, has led to a further reduction in the mortality. Resection of longer segments of the upper ribs has led to a more selective collapse. The tendency is to resect only two or three ribs at one time, especially in patients who are poor surgical risks. The periosteum and intercostal bundles are left in place so that the ribs will regenerate and fix the chest wall in collapse. However, a number of surgeons have followed Head's suggestion of using a chemical, such as Zenker's solution, or Meiss' suggestion of using 10 per cent formalin to prevent regeneration of the ribs, or at least to delay their re-formation. More satisfactory results have been obtained by some surgeons with the use of 10 per cent formalin. The periosteal beds should be formalinized if it is planned to do more than two stages or to separate a planned two-stage thoracoplasty by an interval of more than three or four weeks. The transverse processes are removed along with the underlying short segments of ribs. The first transverse process is only partially removed because it does not interfere with pulmonary collapse and because of the proximity of the eighth nerve root of the brachial plexus. Removal of the transverse processes results in a more complete collapse of the mesial portion of the lung which occupies the costovertebral gutter. Although this added maneuver contributes to the development of scoliosis, its advantages in cavity closure more than compensate for the additional deformity. Holst and Semb added apicolysis to the standard partial thoracoplasty. This brings about vertical collapse of the apex of the lung.

These modifications of the classical Wilms-Sauerbruch thoracoplasty are advantageous. The resection of long segments of the upper ribs is indicated because the most advanced disease is usually located in the upper portion of the lung. Since resection of the upper ribs collapses the most diseased portion of the lung, considerable improvement may be expected to follow this procedure, even though the second

stage is delayed. On the other hand, if the lower ribs are removed at the first stage and the operation is not completed, little improvement will be obtained. Furthermore, when the resection is from above downward, collapse of the chest wall is gradual, but when the operation is done from below upward, little collapse occurs until the upper ribs are resected, when there is a rapid collapse of the entire chest wall. By doing the operation in multiple stages, shock rarely results and the postoperative reaction is less severe in every way.

The number of operative stages depends not only upon the number of ribs it is necessary to resect to effectively collapse the lesion, but also upon the patient's general condition. All the ribs lying above the cavity as well as two or more ribs lying below the cavity should be resected. It is not possible always to prognosticate accurately the number of ribs it will be necessary to resect, for cavities may descend as much as 3 cm. following removal of the ribs superior to the lesion. Roentgenograms two weeks following each stage will show the extent of cavity descent, and the last stage of the thoracoplasty should be carried two ribs below the level of the cavity. It is our practice to remove the third rib to within 3 to [illegible] cm. of its costal cartilage, the entire second rib, and all the first rib and a portion of its cartilage during the first stage in good-risk patients. The transverse processes are also removed In this group of patients as many as three ribs may be removed at the second stage, but frequently the scapula will ride on the seventh rib. Resection of the seventh rib or the inferior angle of the scapula may be necessary to prevent this. In order to obviate the pain associated with the scapula riding on the seventh rib and to gain a more effective collapse by permitting the scapula to fill the costal defect, we prefer resection of the inferior angle of the scapula as recommended by Holman when only a five- or six-rib thoracoplasty is necessary. In poor risk patients the three stages of a seven-rib thoracoplasty may comprise two and one-half, two and one-half, and two ribs Even this may lead to serious reaction in poor-risk patients, and consequently it may be necessary to remove only one rib at a time. The majority of patients will require resection of six or seven ribs, and this usually can be carried out in two or three stages. The fourth, fifth, sixth, and seventh ribs in a seven-rib thoracoplasty are resected, so that the resulting defect in the bony thorax resembles an inverted cone.

The interval between stages should be three weeks, so as to permit adequate recovery of the patient from the previous operation. Paradoxical motion of the chest wall associated with a rapid pulse or low vital capacity, wound infection of even a minor degree, reactivation of an old lesion or bronchogenic spread require postponement of the next stage. Unexplained febrile episodes and increased activity of extrapulmonary tuberculous lesions also require careful appraisal before proceeding with further stages.

Preoperative preparation of the patient consists of correction of secondary anemia by blood transfusions, a survey to exclude extrapulmonary tuberculosis when symptoms suggest involvement of the gastrointestinal tract, genitourinary system, or osseous structures, and an appraisal of the patient's response to exercise. Ambulation is insisted upon, whenever possible, prior to operation because of its invigorating effects, including improvement of muscle tone. Streptomycin is not administered routinely either before or after operation because in well-selected cases there is a low incidence of reactivation and of bronchogenic spread. Resistance of the organism to streptomycin has been shown to develop rather uniformly after six to

eight weeks of treatment, and it is likely that a number of thoracoplasty patients would harbor this type of organism if treated one week before and two weeks after each stage. Transfusions are given during or after each stage. Blood volume studies show that a greater amount of blood is lost during the operation and in the immediate postoperative period than is usually estimated by the surgeon.

Cyclopropane, nitrous oxide and oxygen, and nitrous oxide-oxygen and ether vapor have proved to be satisfactory inhalation anesthetic agents for thoracoplasty. The ease and rapidity of induction, the ability to maintain high concentrations of oxygen in the blood, and the brevity of the recovery period are factors which make cyclopropane the preferable anesthetic agent. It would appear that the advantages of local anesthesia, except under unusual circumstances, have been overestimated However, the cough reflex is maintained during operation, which should prevent to some extent a spread of the tuberculosis. Also the surgeon can proceed with deliberation and care so that there is less trauma to tissues, less hemorrhage, and less danger of injury to the pleura or other structures. An analysis of 795 thoracoplasty stages shows that the incidence of bronchogenic spread in 61 patients receiving local and regional anesthesia was twice as high as the incidence of spread in the remaining patients who received inhalation anesthesia. However, this higher incidence of spread can be attributed, at least in part, to the fact that local anesthesia was employed in poor-risk patients.

If local anesthesia is used, phenobarbital sodium or Nembutal is given about one hour before the patient is taken to the operating room, and morphine, 1/8 grain, and atropine, 1/150 grain, are injected hypodermically one-half hour before the operation is begun The skin along the line of the proposed incision should be infiltrated thoroughly with 1/2 per cent procaine solution to which epinephrine has been added, one drop to each 30 c c. of procaine solution. The subcutaneous tissues and muscles on each side of the proposed incision are infiltrated in a fan-shaped manner with the same solution. After the incision has been carried through the skin, subcutaneous tissue, and muscles, it is possible to gently retract the scapula anteriorly, which affords ready access to the intercostal nerves proximal to the ribs' angles. Regional anesthesia is established by injecting 1 per cent procaine solution in and about the intercostal nerves which lie below the lower border of the ribs. The second through the eighth intercostal nerves are treated in this fashion. Care must be exercised as to the amount of procaine solution employed, for serious reactions accompany the use of this agent. It is best not to use more than 250 c.c. of 1/2 per cent solution and 50 c c. of 1 per cent solution in any case.

The patient is placed in a lateral and slightly prone position, with the diseased side uppermost, and the arm on that side is allowed to hang over the edge of the table so that the scapula can be freely displaced forward. A Coryllos thoracoplasty brace is used to support the anterior surface of the chest while the flexed dependent thigh prevents the trunk from rolling forward. The skin incision extends from about 6 cm below the upper border of the trapezius muscle and about [illegible] cm from the second thoracic spinous process downward and slightly medially to one fingerbreadth below the inferior angle of the scapula, then outward to the posterior axillary line (Fig. 409). The incision is carried down rather close to the spine so that only narrow segments of the trapezius and rhomboid muscles have the nerve supply destroyed The auscultatory triangle is developed and the incision is carried through

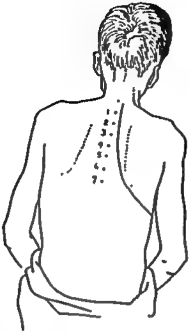

Fig 409.—Incision for resection of the upper ribs as the first stage of a posterior extrapleural thoracoplasty.

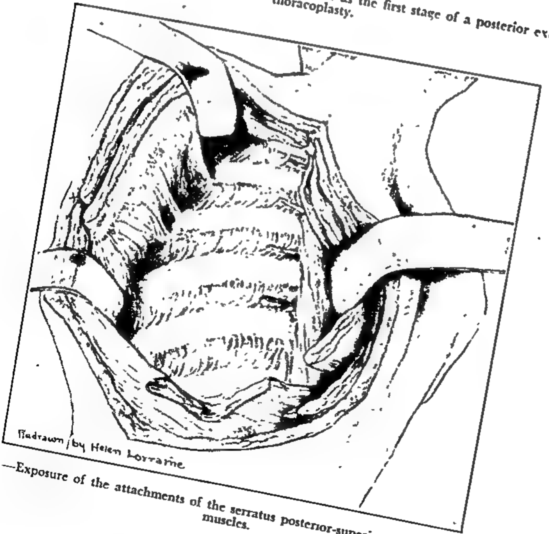

Fig 410.—Exposure of the attachments of the serratus posterior-superior and serratus anterior muscles.

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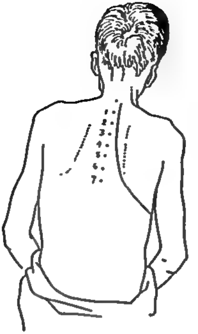


Fig. 409.—Incision for resection of the upper ribs as the first stage of a posterior extrapleural thoracoplasty.

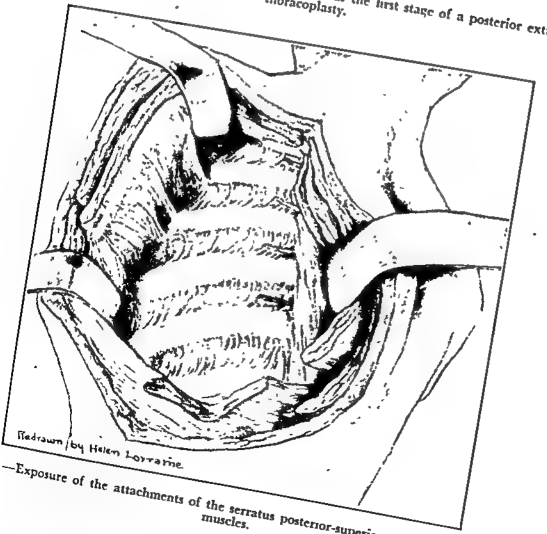


Fig. 410.—Exposure of the attachments of the serratus posterior-superior and serratus anterior muscles.

the trapezius and rhomboid muscles, dividing only short segments of these muscles at a time so that bleeding vessels may be carefully clamped and ligated as the operation proceeds. A short segment of the latissmus dorsi muscle is cut transversely. In order to avoid the loss of excessive amounts of blood during the division of muscles, Carter suggests exposure of the auscultatory triangle which lies just below and medial to the angle of the scapula The trapezius and rhomboid muscles are then separated from the underlying bony thorax from below upward and divided while the operator compresses a segment of them between his thumb and fingers on one side

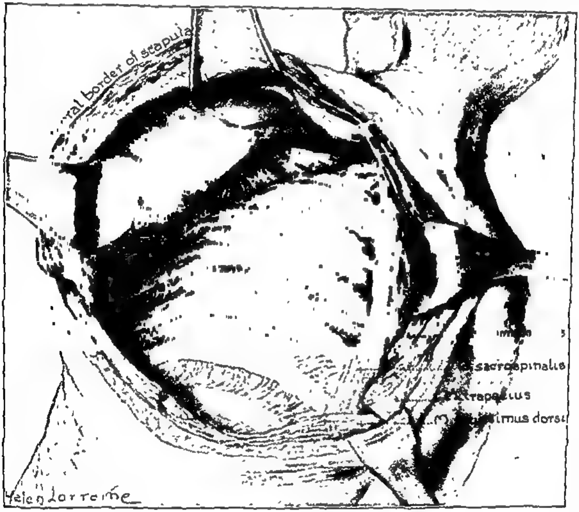


Fig. 411.—Exposure of upper ribs following division of costal attachments of posterior superior serratus and anterior serratus muscles. *Note the close relationship between the upper attachment of the anterior serratus muscle and the axillary vessels.*

of the line of incision and the assistant does the same on the opposite side. The vessels are clamped as they are exposed. In this way the heavy muscles may be divided completely without loss of blood. This incision is adequate for exposure of the upper seven ribs and the respective transverse processes The scapula is detached from the bony thorax by sharp and blunt dissection and retracted anteriorly and upward by heavy retractors (Fig. 410). This places the serratus anticus muscle on stretch and by blunt dissection the upper digitations are developed and divided 1 cm. from their costal origin down to the level of the fourth rib. The fatty tissue of the axilla is pushed anteriorly and the scapula may now be retracted away from the ribs with little effort (Fig. 411). The insertion of the posterior superior serratus

muscle is divided. The sacrospinalis muscles are separated from the upper four ribs and retracted toward the midline so that the posterior ends of the ribs are exposed. The third rib is resected first, then the second and the first, as exposure of the latter ribs is made less difficult when they are resected in this order.

The periosteum is incised over the outer surface of each rib from the tip of the transverse process as far forward as is indicated, in the upper ribs to the costochondral junction. The periosteum is freed entirely from the dorsal surface of the third rib proximal to its angle and a periosteal elevator is passed forward and then backward, completely denuding the rib's dorsal surface of periosteum. A one-half curved periosteal elevator is passed beneath the rib posteriorly and carried forward above and then backward below the rib, freeing its inner surface from the periosteal bed. This plan is followed because of the direction taken by the fibers of the external intercostal muscles. The rib is divided posteriorly at the tip of its transverse process. The severed rib is grasped posteriorly with the hand or a heavy forceps and retracted outward and anteriorly. This maneuver gives more room for manipulation of the blunt periosteal elevator used to free the rib from its internal periosteum, and at the same time protects the pleura from injury. The internal surface of the rib is freed in this manner as far anteriorly as indicated. The intercostal muscles are freed from the anterior portion of the partially denuded rib by passing a sharp elevator forward along its superior border and by drawing it backward along the inferior border of the rib. All the ribs other than the first are treated in this manner. In removing the first rib, it should be recalled that it is in close contact anteriorly and laterally with the subclavian vessels and the cords of the brachial plexus, while anteriorly near the sternum the internal mammary vessels and innominate vein are directly posterior to the cartilage. The outer or inferior edge of the first rib is turned toward the operator and it is denuded of its periosteum. This permits freeing of the superior and inferior surfaces of the first rib by a blunt periosteal elevator. The inner surface of the first rib is freed of its periosteal attachment by a special ¾ curved periosteal elevator which prevents injury to the brachial plexus. The first rib is grasped with a Lane bone-holding forceps and severed at its junction with the tip of its transverse process. The rib is retracted outward and downward and the insertion of the scalenus anticus mucle is developed by blunt dissection and severed. The periosteum is carefully freed from the remaining portion of the first rib anteriorly by a blunt periosteal elevator. Partial resection of the first cartilage follows removal of the first rib.

A warm saline pack is placed over the decostilized portion of the chest wall while the transverse processes are excised. The periosteum is freed from the inner aspect of the necks of the ribs after strong posterior retraction of the sacrospinalis muscles. It is necessary to divide with scissors the insertion of a few bundles of the sacrospinalis muscles into each transverse process. The index finger is interposed between the pleura anteriorly and the rib's neck and the transverse process posteriorly. The intertransverse ligaments are divided with scissors and by blunt dissection with an Alexander periosteal elevator. The stump of the rib and the transverse process are excised with a modified Sauerbruch rongeur. Dry gauze is inserted into the bed of each transverse process after its resection, and firm pressure is applied, thus controlling hemorrhage from this region.

The inferior angle of the scapula may be resected by making a V-shaped incision about the angle. If the operation is carried out under local anesthesia, the

muscles are freed on the under and outer surfaces of the bone by means of the electrosurgical unit. Bleeding is controlled and the periosteum is destroyed by electrodesiccation. It is not safe to use the electrosurgical unit during cyclopropane anesthesia and in such cases the inferior angle of the scapula is subperiosteally resected and the periosteum is treated with 10 per cent formalin solution. The extent of scapula resection depends upon the number of ribs which have been resected; more of the scapula will need to be removed in a five-rib thoracoplasty than in a six-rib thoracoplasty.

The wound is washed thoroughly with saline solution, and devitalized muscle fragments are excised. The wound is carefully inspected for bleeding prior to closure. The scapula is brought down into place and the transected muscles are closed in a single layer with a running suture of chromic No. 1 catgut. The deep fascia of the skin and superficial muscle fascia are approximated as a single layer with interrupted sutures of No. 60 cotton. The skin is closed with interrupted sutures of cotton. The wound is not drained.

The second and subsequent stages of a standard seven-rib thoracoplasty are carried out through the original incision. It is neither necessary nor desirable to open the entire original incision for exposure of the sixth and seventh ribs during a third-stage thoracoplasty, but only the inferior two-thirds of the wound. Fine catgut is used for hemostasis and for wound closure other than the skin in all stages except the first. The wounds are drained by split rubber tube drains in the second and third stages, either through the inferior angle of the wound or through a stab wound in the inferior musculocutaneous flap.

For the first twelve to twenty-four hours after operation the foot of the bed is elevated and the patient is turned from the back to the affected side, but not to the sound side. The nursing staff is instructed to support the thoracic wall during cough so that the sputum is evacuated more effectively. Paradoxical chest wall motion is controlled by strapping the chest and occasionally by the use of shot bags. Morphine is administered in sufficient dosage to control pain, but care must be exercised because of the likelihood of abolishing the cough reflex by large doses. A wet tracheobronchial tree is combated by intratracheal suction and at times it is necessary to perform bronchoscopy Blood transfusions are given whenever indicated. Reactivation or bronchiogenic spread is treated with antibiotics. Ambulation is desirable between stages. Prolonged sanatorium supervision and bed rest are necessary, usually for six months to one year.

In debilitated and poor-risk patients, the first stage of a posterior extrapleural thoracoplasty may be carried out through a slight modification of the transverse incision which has previously been described by Bigger. The patient is placed in the position used for the complete upper stage thoracoplasty. The incision extends from the tip of the first dorsal spine to the junction of the middle and outer thirds of the spine of the scapula (Fig 412). The trapezius muscle is separated in line with its fibers, care being taken not to injure the branches of the spinal accessory and the second, third, and fourth cervical nerves which pass down on the undersurface of this muscle and supply it They are usually found near the spine of the scapula The trapezius muscle is separated from the underlying structures above and below the line of incision, exposing the junction between the superior rhomboid and the levator scapulae muscles (Fig. 413). These muscles are then separated, the levator scapulae being retracted upward and laterally and the superior rhomboid downward

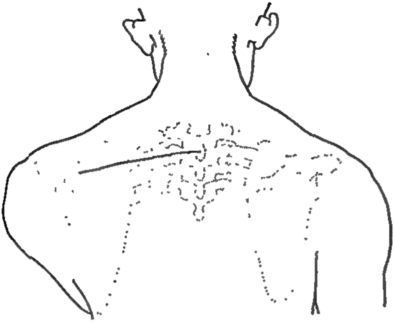


Fig. 412.—Transverse muscle-splitting incision for exposure of the upper two ribs.

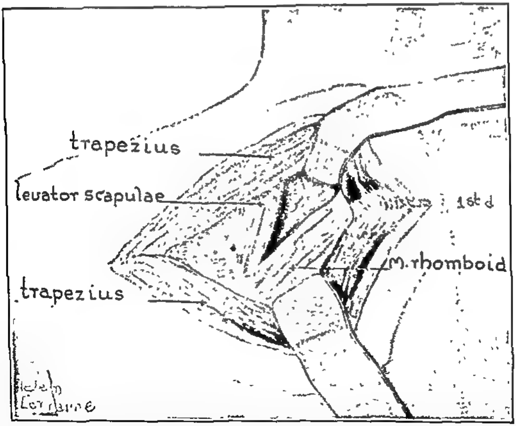


Fig. 413—The trapezius muscle has been separated in line with its fibers, and the levator scapulae and rhomboid muscles are being separated from each other.

and medially. A branch of the fifth cervical nerve passes downward and medially in the upper medial portion of the field to supply the rhomboid muscles. It must be protected. The posterior superior serratus muscle is divided near its attachment to the ribs and the splenius capitis and semispinalis capitis muscles are freed and retracted toward the midline. This incision gives a satisfactory exposure of the first and second ribs, and a short posterior segment of the third rib can be removed in patients with thin muscles (Fig. 414). In heavily muscled individuals the exposure is unsatisfactory.

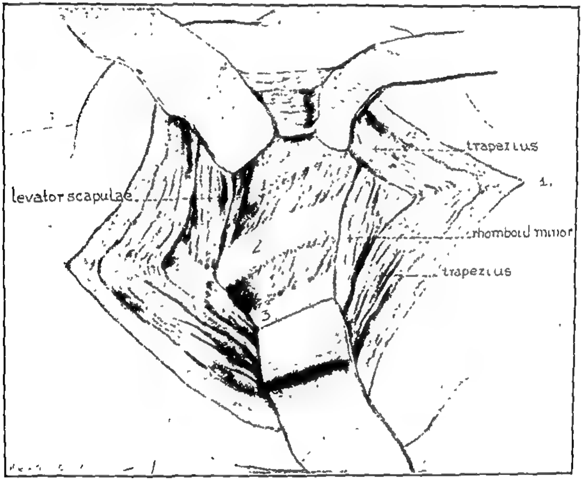


Fig 414 —Length of ribs which may be exposed by the transverse muscle-splitting incision

When the first stage is carried out through a transverse incision, the standard incision which curves around the inferior angle of the scapula is used for the second and subsequent stages. An additional segment of the third rib is removed at the second stage.

THORACOPLASTY WITH EXTRAFASCIAL APICOLYSIS

The necessity for vertical collapse of the lung in certain cases has been repeatedly emphasized by Holst. Semb stressed the importance of preserving the periosteum and intercostal muscles so that the regenerated ribs would maintain the downward displacement of the apex of the lung. This procedure was carried out in an extrafascial plane and is commonly referred to as extrafascial apicolysis (Fig. 415). Semb pointed out that there was less danger of entering infected zones or rupturing into superficial cavities if lysis of the apex of the lung was extrafascial rather than

extrapleural. Extrafascial apicolysis is usually performed in connection with the standard first-stage thoracoplasty. It may be done at the time of revision of an unsatisfactory thoracoplasty but naturally carries greater danger when so used.

Experience has shown that combined apicolysis and thoracoplasty has certain distinct disadvantages and should be used only in well-selected cases. This addition to the standard thoracoplasty has resulted in a higher mortality and an increase in the incidence of wound infection and bronchogenic spread of the disease. On the other hand, there has been a higher percentage of sputum conversion in this group of patients than in those subjected to the standard thoracoplasty alone. The complications of extrafascial apicolysis indicate that this procedure should be used only in apical and medially located cavities.

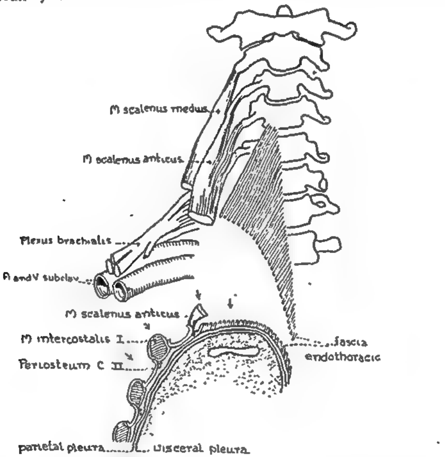


Fig. 415—Extrafascial pneumonolysis (Semb). Note the descent of the intercostal structures and periosteum along with the lung and pleura.

Extrafascial apicolysis should be considered a supplementary procedure to the standard posterolateral first-stage thoracoplasty. After resection of the upper three ribs and their respective transverse processes, better access to the apex of the lung can be obtained by dividing the periosteum of the upper three ribs and the adjacent intercostal bundles posteriorly (Fig. 416).

The apex of the lung is first separated from the neurovascular bundle. The dissection usually begins immediately beneath the lateral portion of these structures where the attachment is frequently quite loose. The entire procedure is carried out extrafascially, thus avoiding the danger of rupture into a pulmonary cavity. If the attachment to the neurovascular bundle is in the form of a broad connective tissue band, it should be separated into several strips which are individually ligated and

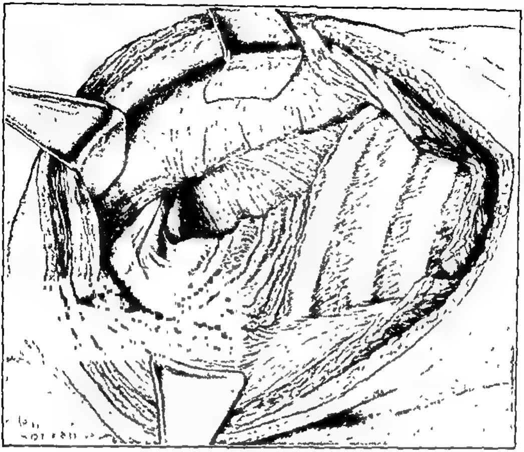


Fig 416.—Semb extrafascial epicolysis, showing fibrous attachments of lung apex in the region of the great vessels and nerves The intercostal structures and the periosteum of the upper ribs have been ligated and divided.

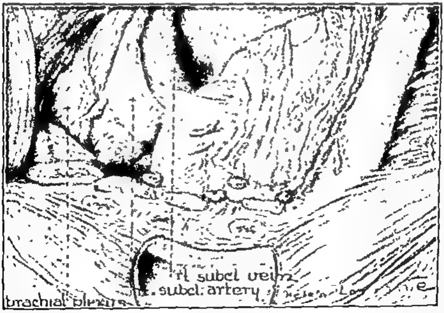


Fig. 417.—Extrafascial apicolysis. Fibrous bands posterior to the nerves and between the nerves and artery have been divided *The fibrous band between the artery and vein still fixes the apex of the lung.*

Fig 418 —Extrafascial apicolysis Separation of lung from mediastinal structures.

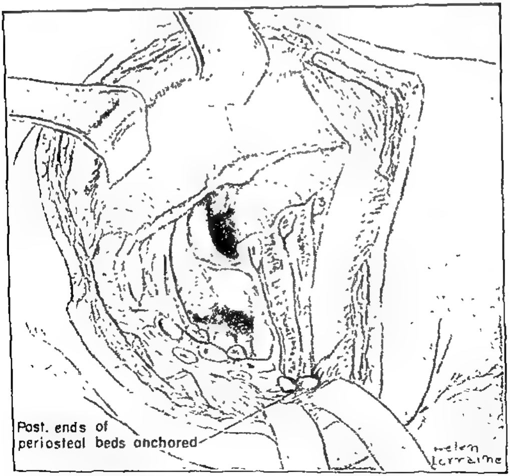


Fig 419 —Following apicolysis the posterior ends of the periosteal beds are sutured together and anchored to the third or fourth intercostal space.

divided. The most definite fascial bands are found posteriorly, around the nerve plexus, between the nerve trunks and the subclavian artery, and between the subclavian artery and vein (Fig. 417). Not infrequently fibers are given off anteriorly from the scalenus anticus muscle to the pleural dome and these also must be divided. Fibrous attachments extending from the transverse processes of the vertebrae and the vertebral bodies to the apex of the pleura posteriorly and medially are isolated, doubly ligated, and divided. While the dissection is being carried out posteriorly and medially, especial care must be used to avoid injury to the posterior segments of the intercostal vessels and to the sympathetic nerve trunk.

After the anterior, lateral, and posterior fibrous bands have been isolated and divided, the attachment of the upper portion of the pleura to the mediastinum must be separated (Fig. 418). Normally, this connection is quite loose and the separation may be accomplished by blunt dissection; but in cases of pulmonary tuberculosis with large cavities located medially, there may be a dense fibrous attachment between the apex of the pleura and the mediastinum. Under such conditions the dissection has to be carried out with especial care to avoid rupture into a cavity. After the mediastinal dissection is completed, the rest of the separation of the apex can usually be carried out by finger dissection.

Semb emphasizes the necessity for careful study of the size and location of the cavity before doing this form of apicolysis, for when the cavity is located posteriorly. it may be necessary to mobilize the apex below the third and sometimes even below the fourth rib posteriorly. After the separation of the apex has been completed, the entire upper portion of the lung descends to the level of the fourth or fifth rib posteriorly and below the cartilage of the first rib anteriorly. The apex of the lung is covered by its endothoracic fascia, and the periosteum and intercostal bundles remain in their normal anatomical relationship to the lung. The posterior ends of the periosteal beds are sutured together and anchored to the third or fourth intercostal space (Fig. 419). If the cavity in the lung is situated posteriorly, the fixation suture is used to pull the apex of the lung anteriorly. Three hundred thousand units of penicillin in physiologic saline solution are placed in the extrafascial space and the wound is closed in layers without drainage. The second or subsequent stages are done at twenty-one day intervals as in the standard thoracoplasty

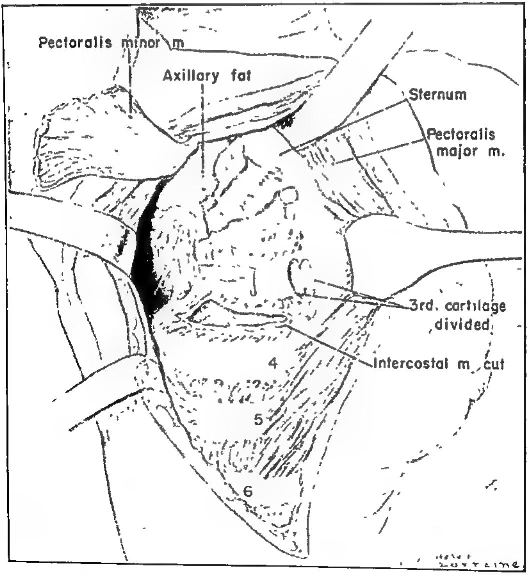
ANTEROLATERAL EXTRAPLEURAL THORACOPLASTY

If sufficient lengths of the ribs are resected through the posterior incision, anterior and lateral resections of the costal stumps and cartilages rarely will be necessary. This operation is used to bring about additional collapse of the lung in those cases where the anterior rib stumps or cartilages appear to be interfering with closure of a cavity. It is also used as a supplementary procedure to the posterior operation in obliteration of empyema cavities

If additional collapse is to be obtained, the anterior operation must follow soon after the second or third stage of the posterior thoracoplasty. The chest wall becomes rigid in the course of two or three months following the first stage of the posterior operation, and little additional collapse can be accomplished after that time by the anterior operation

The patient is placed in the dorsal recumbent position and the arm is hyperextended and adducted with the elbow flexed, which permits relaxation of the pec-

A.



B.

Fig. 420.—*A.* Skin incision for anterior ... horacoplasty in which the first two ... the upper three ribs ... The third ca... d muscles are divided in the third i... ...ward.

toralis major muscle. The skin incision begins at the apex of the axilla 4 cm. mesial to the border of the anterior axillary fold. It is carried outward into the axilla, traversing the thoracomammary fold in the female, and then anterior to the upper border of the seventh rib just lateral to the mammary line (Fig. 420, *A*). The axillary fascia is divided and the lateral border of the pectoralis major muscle is identified. This muscle is elevated from the chest wall by blunt and sharp dissection, and retracted forward. The digitations of the pectoralis minor muscle are divided and this structure is retracted laterally, exposing the ribs and cartilages. The first and second costal cartilages are resected subperichondrally along with whatever rib stumps are present. The stump of the third rib is removed and its cartilage is divided adjacent to the sternum after the method of Haight (Fig. 420, *B*). If the stumps of the fourth, fifth, and sixth ribs overlie a cavity, they are partially resected. The wound is closed in layers and drainage is established for a period of forty-eight hours, using a soft rubber tube drain.

REVISION THORACOPLASTY

Failure to close a cavity by primary posterolateral thoracoplasty may result from resection of an inadequate number of ribs or length of ribs and from failure to resect the transverse processes. Thickened pleura and positive pressure cavities also are frequent causes of thoracoplasty failure. Revision operations are primarily indicated for those cases which do not have a good anatomical collapse following the primary thoracoplasty.

The operation is performed under general anesthesia. The superficial scar resulting from the previous thoracoplasty is excised and the incision is carried through the scar in the muscle layer down to the bony thorax. The scapula and soft tissues are mobilized from the chest wall by sharp and blunt dissection and retracted anteriorly. The uppermost normal rib is resected subperiosteally for a short distance, which gives access to the undersurface of the regenerated rib above. It is well to remember that it requires from three to four months for a regenerated rib to become solid and suitable for resection. The periosteum is incised over the regenerated ribs and a blunt periosteal elevator is used to free them from their periosteum. Short segments, denuded of periosteum, are grasped with bone-holding forceps, which aids in freeing the remainder of the regenerated rib from its periosteum. Frequently, the vertebral stumps of the ribs are fused into a bony plate which requires division by bone shears. It may be necessary to remove additional lengths of the anterior costal stumps as well as the transverse processes.

DRAINAGE OF PULMONARY CAVITIES

One of the oldest surgical methods of treatment of tuberculous cavities consists of external surgical drainage. This procedure has been undertaken by numerous surgeons with enthusiasm, only to be abandoned because of the complications and poor results. In 1939 Monaldi aroused further interest in cavity drainage by introducing a closed suction type of external drainage. Following Hinshaw and Feldman's introduction of streptomycin in the treatment of clinical tuberculosis in 1945, cavity drainage appeared more promising.

The most common indication for closed drainage (Monaldi) is the presence of a positive pressure cavity where the general condition of the patient or the extent of

the disease precludes other forms of surgery. Occasionally this method may be applied to a residual tension cavity following thoracoplasty. Results show that this method of treatment is not definitive but usually must be followed by thoracoplasty or by some other procedure. The toxemia associated with positive pressure cavities frequently is relieved and the cavity decreases in size and occasionally may be obliterated. The introduction of the catheter is a simple procedure. The cavity is localized by roentgenograms. Usually the second intercostal space in the midclavicular line is selected for introduction of the trocar. If the pleura is not adherent anteriorly as demonstrated by careful testing with a needle and pneumothorax machine, the cavity is approached by way of the axilla. The trocar is introduced through an intercostal space under local anesthesia. After it has been determined that the trocar lies within the cavity, a catheter of suitable size is threaded through the trocar, which is then removed. The catheter is anchored to the skin, connected with an underwater seal, and suction is applied. The method of Wells and Gordon whereby drainage of giant apical cavities is preceded by resection of the upper three ribs and their respective costal cartilages to the midaxilla is very satisfactory. The Monaldi tube is inserted through an anterior approach three weeks following the anterior thoracoplasty. Suction is instituted, and as soon as the general condition of the patient permits, the posterior thoracoplasty is carried out, without coming in contact with the Monaldi tube.

External, surgical or open drainage is indicated in secondarily infected tuberculous cavities and in residual cavities following thoracoplasty, when the general condition of the patient or the extent of the disease contraindicate lobectomy or pneumonectomy. The results of external surgical drainage are quite satisfactory in the solitary residual cavity following thoracoplasty, but multiple residual cavities are best treated by resection unless the disease in the contralateral lung excludes this method of treatment. It is likely that streptomycin will become an important adjunct to the drainage of cavities which have not been preceded by thoracoplasty. The technic of external drainage of tuberculous cavities is similar to that employed in the drainage of lung abscess and may be done in either one or two stages. Symphysis of the two layers of pleura must exist at the time of drainage. Eloesser makes a U-shaped skin flap at the first stage of his two-stage operation. The base of the flap lies over the rib to be resected and the incisions run at right angles to the rib. The rib overlying the lower border of the cavity is resected with its periosteum. Five centimeters or more of the rib are removed and the edge of the skin flap is fastened to the pleura at a suitable distance from its tip. The tip of the skin flap must be left long enough to be led into the bottom of the cavity at the second stage The skin flap is held against the underlying chest wall by packing. After a period of two or three weeks, the cavity is opened and the free tip of the skin pedicle is pushed into the cavity and held in place by a petrolatum gauze pack. Spontaneous healing will take place in a reasonable number of cases; however, a muscle transplant for obliteration of the epithelized cavity frequently becomes necessary.

PNEUMOPERITONEUM

The artificial injection of air into the peritoneal cavity was used for a period of sixty years in the treatment of tuberculous peritonitis and enterocolitis before it was first recognized by Vajda in 1933 that the procedure was of value in the treatment

of pulmonary tuberculosis. Since that time, pneumoperitoneum, with or without diaphragmatic paralysis, has provided a simple, reversible method of collapse of the lung. The greater safety of pneumoperitoneum and its freedom from a variety of serious pulmonary and pleural complications are distinct advantages over intrapleural pneumothorax. The application of pneumoperitoneum to hopelessly advanced cases has led some clinics to question the effectiveness of this method of collapse. Others recommend the procedure enthusiastically and have practically stopped using intrapleural pneumothorax. Effective intrapleural pneumothorax remains the most satisfactory collapse measure for pulmonary tuberculosis, but to avoid the more common dangers associated with its use one has to exclude many patients from that form of treatment. Fortunately, many of them will respond favorably to pneumoperitoneum.

Pneumoperitoneum is used chiefly in the treatment of acute, exudative, parenchymatous disease, unilateral or bilateral, with or without cavitation, where other collapse measures are inadvisable because of the nature or extent of the disease. It is the treatment of choice where artificial pneumothorax is indicated but cannot be established or has proved unsatisfactory. Basal and hilar cavities may be successfully treated by pneumoperitoneum. It is especially useful in controlling contralateral or ipsilateral acute disease associated with a cavity which requires thoracoplasty. Frequently, pneumoperitoneum is used to control the exudative lesion preliminary to intrapleural pneumothorax, thoracoplasty, or even pulmonary resection. It may be used successfully in the control of pulmonary hemorrhage in bilateral disease where the origin of the hemorrhage cannot be localized with certainty.

There are few absolute contraindications to pneumoperitoneum. The hopelessly advanced case frequently show a reduction of toxemia and improvement of symptoms when treated by this method. However, Banyai concludes from his wide experience with pneumoperitoneum in the treatment of tuberculosis that generalized tuberculosis, amyloidosis, cardiac decompensation, diseases of the coronary arteries, plastic peritonitis with palpable masses, respiratory insufficiency, and fixation of the diaphragm by adhesions on the diseased side, are contraindications to this method of collapse.

There still is controversy as to the desirability of performing a phrenic nerve interruption in association with pneumoperitoneum. Paralysis of one side of the diaphragm results in a greater elevation of the diaphragm with a more effective unilateral collapse than can be accomplished by the use of either procedure alone. Paralysis of the ipsilateral diaphragm is therefore indicated when pneumoperitoneum is used in the treatment of unilateral disease. In the treatment of bilateral disease, it is necessary to weigh carefully the indications for diaphragmatic paralysis. In such instances the air in inclined to gravitate beneath the paralyzed hemidiaphragm, and the disease on the contralateral side may benefit little or may even progress in spite of the pneumoperitoneum.

Phenobarbital sodium may be administered hypodermically one hour before the initial pneumoperitoneum in the highly nervous patient; however, sedation is usually unnecessary. The site generally used for injection of air is at a point 5 cm. to the left of the umbilicus on an imaginary line connecting the left anterior superior iliac spine with the umbilicus Equally satisfactory injections may be made on the right side—in the midline below the umbilicus, or just below the

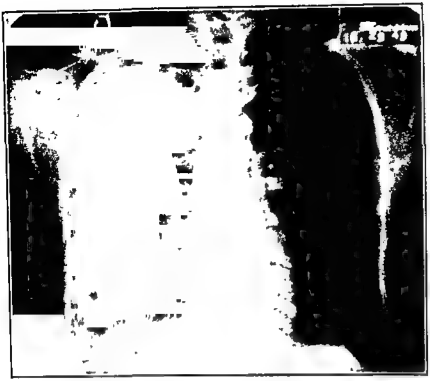


Fig. 421.—Far-advanced pulmonary tuberculosis with cavitation, right mid-lung field

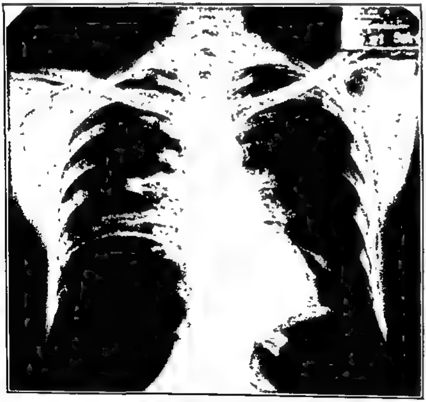


Fig 422.—Same case as Fig 421 Large cavity closed by pneumoperitoneum and auxiliary temporary phrenic nerve paralysis (right).

costal margin in the left nipple line. In selecting the site for injection of air, surgical scars should be avoided because of the likelihood of intestinal loops being adherent to the abdominal wall. The abdominal wall is prepared with ether and tincture of Merthiolate. The skin, subcutaneous tissue, and peritoneum are anesthetized with a 1 per cent solution of procaine using a 25 gauge needle. The skin is punctured with a sharp-pointed scalpel. A 5 cm., 19 gauge, short-beveled needle is attached to a 2 c.c. hypodermic syringe filled with 1 per cent procaine solution. The needle is advanced through the abdominal wall, traversing slowly the fascial layers, which offer greater resistance; however, by rotating the syringe and making steady, firm pressure this resistance is easily overcome. The free flow of procaine solution from the syringe usually indicates that the needle tip lies within the peritoneal cavity. Before proceding with the injection of air, the plunger of the syringe is pulled backward in order to make certain that the needle has not entered a blood vessel. The needle is connected with a pneumothorax apparatus, and 50 c c. of filtered air are injected. Usually there is no rise in the manometer reading if the air has entered the peritoneal cavity. If the flow of air is slow and the manometric pressure is positive on completion of the initial injection, it can be assumed that air has been forced into the tissue spaces outside the peritoneal cavity. After it has been determined that the needle lies within the peritoneal cavity, it is advanced for a distance of 5 mm. and additional air is slowly administered. Pain at the site of injection suggests that the opening of the needle may be extraperitoneal and its position should be checked again. Pain in the shoulder, abdominal discomfort or aching, and tightness in the epigastric region are frequent complaints after the intraperitoneal injection of air. The manometer readings are not always easily obtained, but they are usually more positive on inspiration and less positive on expiration. The initial injection varies from 400 to 800 c.c. of filtered air, depending upon the patient's reaction. The average amount of air given at the initial treatment is 500 c.c. *During the first week refills are administered every other day; twice per week* will generally suffice during the second week. After this period, refills may be given at intervals of one week and later extended to two weeks. The average amount for maintenance is 1,000 c.c. of air per week, but the amount of each injection depends upon the peritoneal capacity of the patient, the rate of absorption, and the interval between refills. If pneumoperitoneum is used as a definitive treatment, refills usually will be necessary for a period of from three to five years, depending upon the individual case (Figs. 421 and 422).

Pneumoperitoneum is accompanied by few serious complications. Careful technic will to a large extent exclude air embolism, subcutaneous emphysema, and mediastinal emphysema. A high incidence of peritoneal effusion accompanies pneumoperitoneum but is of little consequence in the majority of cases. If a large effusion persists or if a subdiaphragmatic tuberculous effusion develops, pneumoperitoneum is discontinued. Subdiaphragmatic adhesions not infrequently develop, but they seldom interfere with treatment. Small air pockets may form or an obliterative peritonitis may result in the complete loss of the space.

PULMONARY RESECTION

Although Tuffier performed the first successful resection of the lung for tuberculosis in 1893, less than 100 cases treated by this method were reported in the literature during the next half century. The unacceptable mortality and the high in-

cidence of serious pulmonary and pleural complications limited the use of this method of treatment until recent years. Streptomycin, improved surgical technic, better case selection, use of the prone position during operation, as advocated by Overholt, and detailed operative care have brought striking improvements in both the immediate and the late results. Our experience, and comparative series of streptomycin and nonstreptomycin cases reported by Bailey and his colleagues, and by Moore and Murphy, attest the value of this antibiotic in preventing operative complications and in making excisional surgery safer.

Excision of the lung should be restricted to those patients for whom the modern type of thoracoplasty or other collapse operations have proved unsuccessful or are likely to do so. Cicatricial stenosis of the bronchus with evidence of poor bronchial drainage and often with secondary suppurative changes in the lung distal to the stenosis constitutes one of the well-established indications for resection. Tuberculous bronchiectasis, secondarily infected tuberculous cavities, and tuberculoma, when associated with a positive sputum or a harassing cough, are accepted indications. If a cavity persists after a good anatomical thoracoplasty, cavernostomy or excisional surgery is indicated. Excisional surgery is used in thoracoplasty cases where multiple cavities exist. Excision is also indicated in patients with a solitary cavity, whose respiratory reserve is adequate and in whom no other active ipsilateral or contralateral disease exists. Failure of collapse to control cavitary lesions of the lingula, of the superior segment of the lower lobe, or of the basal segments of the lower lobe constituted the indication for resection in 20 per cent of a series of sixty cases. Serious consideration should be given to pneumonectomy in those cases with extensive unilateral disease with cavitation in both or all the lobes. At present, resection should not be performed on patients if thoracoplasty has a reasonable chance of success. Further experience may alter this concept.

During the preoperative studies the cardiac and respiratory reserve should be carefully appraised in order to avoid causing postoperative pulmonary insufficiency or respiratory cripples. The general condition should be sufficiently satisfactory to indicate that the patient will withstand such a major operation. Serious nontuberculous disease or extensive extrapulmonary tuberculosis contraindicate pulmonary resection. Acute progressive or unstable pulmonary tuberculosis generally contraindicates excisional surgery. Acute tuberculosis associated with a cavity may respond readily to streptomycin and this may give a false sense of security relative to the time of operation. Not infrequently one observes reactivation or recrudescence of these lesions which were apparently controlled by streptomycin prior to resection. Contralateral acute tuberculosis should be quiescent or arrested for a period of nine months to one year prior to resection. Associated ipsilateral acute disease requires a shorter period of observation, providing the lesion is limited to the lobe to be resected. Ulcerative tuberculous bronchitis is a contraindication to resection if the bronchus must be amputated through the area of ulceration. This lesion usually responds well to streptomycin.

Inhalation anesthesia, such as gas-oxygen-ether, or cyclopropane is administered through an intratracheal tube. The position of the patient on the table will depend upon the lobe to be resected in lobectomy and the state of the pleural cavity in pneumonectomy. The upper lobes are removed through the third intercostal space anteriorly with the patient in the dorsal recumbent position and tilted toward the diseased side. The lower lobes are removed through a posterolateral approach

with the patient in the Overholt position (Fig. 423). If the pleural space is free of serious adhesions and is noninfected, pneumonectomy is performed through the third intercostal space anteriorly. If pneumonectomy is accompanied by a simultaneous pleurectomy for tuberculous empyema, a posterolateral approach is made *with the patient in the face-down position. It is technically easier to perform a* pneumonectomy through a posterolateral approach in the presence of marked pleural symphysis or dense pleural adhesions. The position of the patient assumes an important role during resections for tuberculosis. It is desirable to keep the lobe or lung to be resected in a dependent position during the operation, thereby helping to prevent bronchogenic spread. The anatomical structures in the hilum of the lung are usually free and are developed and treated in the manner described elsewhere.

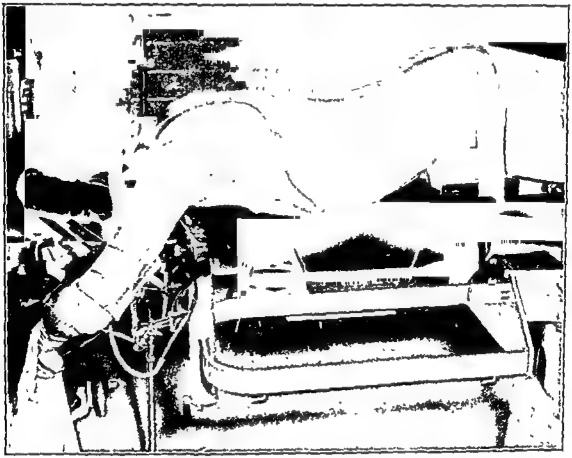


Fig. 423.—Table devised by Richard Overholt permits face-down position for pulmonary resections in the treatment of pulmonary tuberculosis

During pneumonectomy, permanent paralysis of the diaphragm is performed by resecting 2 cm. of the intrathoracic epipericardial portion of the phrenic nerve before closure of the wound. Following removal of a lobe the pleural cavity is drained by a No 32 rubber catheter which is led up to the dome of the respective hemithorax from the ninth intercostal space in the posterior scapular line. Additional openings are made in the intrathoracic portion of the rubber tube to permit drainage from the dependent portion of the thoracic cavity. A No. 30F mushroom catheter is introduced through the second intercostal space in the midclavicular line. In segmental excisions it is advisable to introduce the anterior drainage tube through the fourth or fifth intercostal space in the midclavicular line Drainage of the tho-

racic cavity following pneumonectomy is a controversial subject. A No. 24 mushroom catheter may be introduced through the second intercostal space anteriorly and used to decompress the pleural cavity, if this becomes necessary, during the first two postoperative days.

Detailed attention must be directed to the evacuation of sputum postoperatively because retention of secretions may lead to spread of the disease. The tracheobronchial tree may be aspirated with a catheter or it may be necessary in certain cases to perform bronchoscopy. The patient is moved frequently from the back to the operative side and the operative side is supported during cough to alleviate pain. Sedation is administered with care because oversedation leads to suppression of the cough reflex. Following lobectomy 15 to 20 c.c. of water of negative pressure is used to aid in reexpansion of the remaining lobe or lobes. The drainage tubes are removed on the second postoperative day. Antibiotics are continued for a period of one to two weeks. Spread of the disease is treated by continuation of the streptomycin therapy. Bronchopleural fistula and empyema are infrequent complications. Permanent paralysis of the diaphragm is performed one month following lower lobe lobectomy or excision of the basal segments. One to two months following upper lobe excision or pneumonectomy, a six- or seven-rib two-stage posterolateral extrapleural thoracoplasty is performed without removal of the transverse processes. Paralysis of the diaphragm or thoracoplasty following lobectomy for tuberculosis prevents overdistention of the remaining lobe or lobes. Thoracoplasty following pneumonectomy prevents the late development of tuberculous empyema and overdistention of the contralateral lung. It is desirable for patients who have undergone pulmonary resection for tuberculosis to continue with sanatorium care for a minimum of one year.

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CHAPTER 36

THE MEDIASTINUM; THYMECTOMY; THORACIC DUCT INJURIES

I. A. Bigger

The mediastinum, especially the posterior portion, is difficult to approach surgically because it is situated deeply between the pleural cavities and is inclosed within a strong bony cage. As a result of this protected position, the accurate diagnosis and localization of mediastinal lesions by physical examination is frequently impossible. Surgery of the mediastinum, therefore, did not make appreciable progress until the development of roentgenography provided a method by which mediastinal lesions could be more accurately localized. Roentgenography also has been of inestimable aid in the diagnosis of mediastinal lesions.

Such important structures as the trachea and primary bronchi, the esophagus, the great vessels, and the vagus nerves pass through the rather limited space encompassed within the normal mediastinum. As a result of this anatomic arrangement, the development of tumors or aneurisms or the accumulation of fluid or air in this area may cause serious pressure symptoms on any or all of these important structures. Tumors and aneurisms, especially the latter, may cause pressure on the air passages, while the more diffusely distributed pressure which results from the accumulation of fluid or air is more likely to interfere with the return flow of blood through the great veins. In either case, the symptoms resulting from increased pressure within the mediastinum may become so acute as to demand emergency measures for their relief. The type of procedure indicated will depend upon the cause of the increase in pressure and also to some extent upon the severity of symptoms. If the condition is due to aneurism of the arch of the aorta or to an inoperable malignant tumor, palliation may be achieved by dividing the sternum longitudinally. This procedure rarely may be indicated as an emergency measure when a circumscribed tumor is causing such serious pressure symptoms that primary removal of the tumor would carry an unjustifiable risk. Should pronounced symptoms develop from pressure by a cyst or encapsulated fluid, temporary relief could be obtained by aspiration.

MEDIAN STERNOTOMY

The extent to which the sternum is divided should be determined by the location of the obstructing mass. When the mass lies within the upper mediastinum near the superior thoracic aperture, it is unnecessary to split the entire sternum, but it is essential that the division be carried well below the site of obstruction. In an occasional case it will be advisable to split the sternum throughout its entire length.

While median sternotomy is not ordinarily technically difficult, it may prove trying to the most resourceful surgeon because of the attending circumstances. When done for the relief of tracheal obstruction, especially when the obstruction is caused by aneurism, it may not be feasible to use an intratracheal tube, and even when the obstruction is due to other causes, the insertion of an intratracheal tube may try the nerve and skill of the most expert anesthetist. When there is marked stridor it is best to anesthetize the larynx and trachea by spraying with Pontocaine or cocaine, and then to intubate before administering a general anesthetic. If it is not possible to introduce an intratracheal tube, the operation may be performed under regional and local infiltration anesthesia, but under such circumstances the undertaking is certain to be trying to all concerned. Pure oxygen or oxygen and helium administered through an ordinary gas mask are of some help. The dorsal recumbent position with the head extended sufficiently to make the suprasternal notch accessible is desirable, but it may be impossible for the patient to remain in the horizontal plane. The operation may then have to be completed with the patient's body elevated—in a semisitting posture.

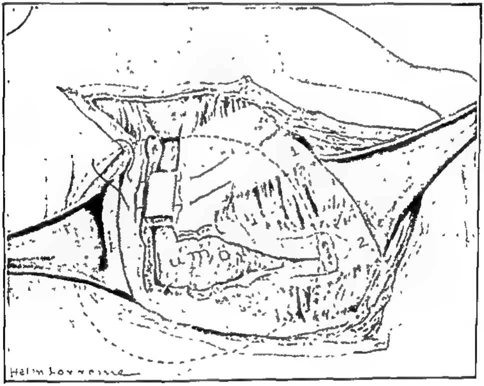

Fig 424.—Mediastinal decompression by median sternotomy and the insertion of a segment of rib or costal cartilage between the sternal segments

Complete median sternotomy is carried out by making a longitudinal incision which is started about 2.5 cm. above the sternum and extended down the midline to a point below the tip of the xiphoid process. The xiphoid is excised and the loose tissue is separated from the posterior surface of the sternum The incision above the sternum is deepened, the communicating arc between the anterior jugular veins is divided between ligatures, and the upper border of the manubrium is exposed. The sternum is then split longitudinally, preferably by a Gigli saw. The substernal structures should be well protected by a narrow malleable retractor while the sternum is sectioned. When the sternum has been completely divided, hemor-

rhage is carefully controlled and measures are taken to keep the sternal segments separated. The xiphoid or a segment of costal cartilage may be fixed between the sternal segments by stainless steel wire sutures (Fig. 424).

If complete longitudinal sternotomy is unnecessary, the following technic may be used. A short transverse incision may be made just above the upper border of the sternum; or the perpendicular incision is started 2.5 to 3 cm. above the sternum as previously described, then carried down the midline to the level of the third, fourth, or fifth costal cartilage, depending upon the lower level of obstruction, and then is curved to the left along that cartilage to the costochondral junction. The incision may be curved to the right if there is a special reason for so doing. The ribbon muscles are separated in the midline, the communication between the anterior jugular veins being clamped, divided, and ligated. The loose tissue is separated from the posterior surface of the upper portion of the sternum by careful finger dissection. The lowest exposed costal cartilage is resected and preserved. The sternal end of the perichondrium is divided and the internal mammary vessels are exposed, ligated, and divided. The tissues are then separated from the sternum from below upward to connect with the dissection which was started above. A narrow segment is removed from the sternum by rongeur for about half of its width, at the level of the resected costal cartilage. A Gigli saw is passed up posterior to the sternum, which is then split longitudinally and the two segments are separated by retraction. The excised costal cartilage is inserted into the longitudinal space between the sternal segments and is fixed by wire sutures. Only the subcutaneous tissue and skin are closed.

This or a similar sternal-splitting incision may be used for the removal of tumors of the anterior superior mediastinum, particularly tumors of the thymus gland Thymectomy for myasthenia gravis is usually best done through a median sternotomy. If wider exposure is needed, the sternum may be completely divided transversely at whatever level seems desirable. When complete transverse sternal division is contemplated, resection of a cartilage is unnecessary. Also, when there is to be complete transverse section of the sternum, the division should be done with a Gigli saw so that the ends can be well beveled, which makes for a more satisfactory closure. Drill holes are then made in the beveled area and the sternal segments are firmly fixed by stainless steel wires, passed through these openings, and snugly tied

The majority of substernal goiters may be removed through a cervical incision, but very large substernal goiters may be more easily and safely removed by combining the usual low collar incision with median sternotomy. True intrathoracic goiters, especially those which descend into the posterior mediastinum, are best removed through a posterolateral thoracotomy incision. The removal of goiters from the posterior mediastinum is certain to be difficult by the cervical approach, whereas they are easily removed through the thorax Sweet, in his interesting paper on this subject, presents a rational explanation for the occurrence of goiter in the posterior mediastinum.

DRAINAGE OF THE SUPERIOR MEDIASTINUM

A low transverse collar incision is made similar to, but usually shorter than, that used for thyroidectomy. The skin, subcutaneous tissue, platysma, and fascia

are dissected up for a few centimeters, and the ribbon muscles of the nec separated in the midline for a sufficient distance to give an adequate exp The communication between the anterior jugular veins is doubly clamped, di and ligated, and the loose tissue in front of the trachea is opened, giving acc the superior mediastinum. When this exposure is used for the evacuation of pus, the dissection should be no more extensive than is necessary.

OPERATIONS FOR TUMORS OF THE MEDIASTINUM

The more complicated incisions, such as those illustrated in Figs. 30, 31 32, are rarely necessary except in aneurisms of the innominate artery or o aortic arch, or in adherent or infiltrating tumors. Even the ingenious trap *incision devised by Kerr (Fig. 425) is not often necessary. Median sterno* gives an excellent exposure for the removal of a limited number of tumors o anterior mediastinum, especially those connected with the thymus gland. only a few exceptions, cysts and tumors of the mediastinum are better appro by one of the standard thoracotomy incisions—posterolateral, anterolateral, o *terior midline—than by the* more complicated procedures. *In general, it i* visable to make the incision anteriorly when the tumor or cyst is anterior posterolaterally when the tumor is posterior. However, very large dermoi teratomas, especially those with a history of infection, are more readily compl removed through the posterolateral approach. The pedicle, or blood supp anterior and may be more satisfactorily secured through the wide exposure affo by the posterolateral approach. The only form of treatment now considere ceptable for dermoids and teratomas is complete extirpation. There are a nu of reasons for this attitude: the incidence of malignant change is high, and i tion is frequent; also, incomplete removal almost invariably results in persi drainage or recurrence of symptoms.

Although dermoids are usually considered by far the most common medias cysts, Blades' report showed a greater incidence of bronchogenic cysts oper upon in the Army thoracic centers. These cysts usually *lie in* close relation to bifurcation of the trachea and are somewhat more frequently found posteri it. However, they may lie anteriorly or between the main bronchi They us are attached to the trachea or one of the main bronchi, and this attachment be to the anterior (cartilaginous) or posterior (membranous) wall. There us is no demonstrable communication between these cysts and the lumen of the tra or bronchus, yet these cysts not infrequently become infected and may rupture the respiratory tract, also, there may be a common wall between the cyst bronchus, which occasionally creates something of a problem at the time of exci of the cyst. Unless care is used, difficulty may be encountered in closure of opening in the bronchial wall. At any rate, it is wise to reinforce the repair b flap of parietal pleura or by suturing the lung surface over it. Complete rem of these cysts is clearly indicated, although the incidence of malignant chang unknown Bronchogenic cysts, like all epithelium-lined cysts, are prone to bec infected, and when infection occurs they may cause serious pressure on the trac or bronchus or may rupture into the tracheobronchial tree.

Simple cysts containing clear watery fluid and lined by flattened mesothe cells are not infrequently found in the angle between the pericardium and c

phragm. These cysts are often referred to as pericardial or pericardial-coelomic cysts. They usually are symptomless but very rarely may extend between the anterior chest wall and the pericardium so as to cause some pressure on the heart. So far as is known, they are not prone to become infected or to undergo malignant change. It would seem, therefore, that they would not require removal, but certain diagnosis is difficult except by thoracotomy, and once exposed, removal is simple.

Fig. 425.—Trap-door incision for the exposure of the anterior mediastinum (Kerr and Warfield). Such complicated incisions are rarely *necessary*.

In individuals who are poor surgical risks and who are suspected of having such a cyst, one might be able to confirm the diagnosis by aspiration through a long slender needle. Since these cysts lie in direct contact with the anterior chest wall and contain thin clear fluid, aspiration through a fine needle should carry a negligible risk. In good-risk patients, exploration and removal is no doubt safer, as these cysts are easily dissected out and the only important structure liable to injury is the phrenic nerve.

are dissected up for a few centimeters, and the ribbon muscles of the neck are separated in the midline for a sufficient distance to give an adequate exposure. The communication between the anterior jugular veins is doubly clamped, divided, and ligated, and the loose tissue in front of the trachea is opened, giving access to the superior mediastinum When this exposure is used for the evacuation of air or pus, the dissection should be no more extensive than is necessary.

OPERATIONS FOR TUMORS OF THE MEDIASTINUM

The more complicated incisions, such as those illustrated in Figs 30, 31, and 32, are rarely necessary except in aneurisms of the innominate artery or of the aortic arch, or in adherent or infiltrating tumors. Even the ingenious trap-door incision devised by Kerr (Fig. 425) is not often necessary. Median sternotomy gives an excellent exposure for the removal of a limited number of tumors of the anterior mediastinum, especially those connected with the thymus gland. With only a few exceptions, cysts and tumors of the mediastinum are better approached by one of the standard thoracotomy incisions—posterolateral, anterolateral, or anterior midline—than by the more complicated procedures. In general, it is advisable to make the incision anteriorly when the tumor or cyst is anterior and posterolaterally when the tumor is posterior. However, very large dermoids or teratomas, especially those with a history of infection, are more readily completely removed through the posterolateral approach. The pedicle, or blood supply, is anterior and may be more satisfactorily secured through the wide exposure afforded by the posterolateral approach. The only form of treatment now considered acceptable for dermoids and teratomas is complete extirpation. There are a number of reasons for this attitude: the incidence of malignant change is high, and infection is frequent; also, incomplete removal almost invariably results in persistent drainage or recurrence of symptoms.

Although dermoids are usually considered by far the most common mediastinal cysts, Blades' report showed a greater incidence of bronchogenic cysts operated upon in the Army thoracic centers. These cysts usually lie in close relation to the bifurcation of the trachea and are somewhat more frequently found posterior to it. However, they may lie anteriorly or between the main bronchi. They usually are attached to the trachea or one of the main bronchi, and this attachment may be to the anterior (cartilaginous) or posterior (membranous) wall. There usually is no demonstrable communication between these cysts and the lumen of the trachea or bronchus, yet these cysts not infrequently become infected and may rupture into the respiratory tract; also, there may be a common wall between the cyst and bronchus, which occasionally creates something of a problem at the time of excision of the cyst. Unless care is used, difficulty may be encountered in closure of the opening in the bronchial wall. At any rate, it is wise to reinforce the repair by a flap of parietal pleura or by suturing the lung surface over it Complete removal of these cysts is clearly indicated, although the incidence of malignant change is unknown. Bronchogenic cysts, like all epithelium-lined cysts, are prone to become infected, and when infection occurs they may cause serious pressure on the trachea or bronchus or may rupture into the tracheobronchial tree.

Simple cysts containing clear watery fluid and lined by flattened mesothelial cells are not infrequently found in the angle between the pericardium and dia-

peculiarities of the thymus, a thin bilobed, elongated structure extending from the lower portion of the neck well down over the pericardium. The thymus at times may reach almost to the level of the diaphragm. It is friable and needs to be handled gently. The arterial supply is by way of the inferior thyroid and the internal mammary arteries, while the venous drainage is into the left innominate vein, immediately posterior to the gland. Clagett splits the sternum from the manubrium to the xiphoid and when the gland has been completely removed approximates the sternum by suturing the periosteum and fascia overlying it with interrupted sutures of catgut or silk.

It would seem safer to bring the bony sternum together with fine wire, passed through drill holes or possibly around the sternum. The structures which must be watched for and protected are the innominate artery and the left innominate vein, the vagus nerves, and the left recurrent laryngeal nerve. Of these, the left innominate vein and the innominate artery ordinarily are in more immediate contact with the thymus.

Postoperatively, there is rarely dramatic improvement, and consequently Prostigmin should be continued and a respirator should be available. Opiates must be given sparingly.

THORACIC DUCT INJURIES; CHYLOTHORAX

The thoracic duct may be injured during the course of operations within the posterior mediastinum, such as those on the thoracic esophagus or the sympathetic chain as well as in nonsurgical wounds of the chest. Blunt force injuries and even violent coughing may cause the duct to rupture. *Unrecognized injury of the* thoracic duct results in the accumulation of large quantities of chyle in the chest cavity, chylothorax, which in the past has shown a mortality of about 50 per cent. Chylothorax also may develop spontaneously, usually the result of involvement of the thoracic duct by malignant tumors such as lymphomas. Nontraumatic chylothorax has an extremely poor prognosis, but traumatic chylothorax, especially that due to surgical trauma, should have a good prognosis if it is recognized and properly treated. During the course of surgical operations within the posterior mediastinum and in the left supraclavicular area, one must keep in mind the anatomical position and relations of the thoracic duct. Van Pernis has reported the results of the examination of more than 1,000 thoracic ducts during the course of postmortem examinations. His findings are therefore important. Two or more branches of the duct were present in 39 per cent, but Van Pernis states that below the level of the eighth dorsal vertebra, there was always a single duct. This finding would appear to have some bearing on the treatment of thoracic duct injuries, especially those occurring below the eighth dorsal vertebra.

Since there have been only a moderate number of reports of surgical injury to the intrathoracic portion of the duct, and still fewer reports of direct surgical attack upon the injured duct, it is not possible to draw final conclusions regarding the effectiveness of the various methods of management of such injuries.

Until recent years the majority of injuries to the thoracic portion of the duct resulted in chylothorax, which usually was treated by nonoperative means although a small number have been treated by indirect surgical attack. The results have been poor from both of these methods of treatment, as might be expected.

Benign solid tumors of the mediastinum most often are of neurogenic origin—neurofibromas, ganglioneuromas, etc. They lie in the posterior gutter in the great majority of instances, although they may occur in any part of the chest. They are usually well encapsulated and generally are easily removed. However, perineural fibroblastomas sometimes occur as dumbbell or collar-button tumors and these present a more difficult problem. Here there is extension through the intervertebral foramen into the spinal canal, which usually requires a laminectomy as well as thoracotomy. Occasionally the intervertebral foramen will have been enlarged by slow expansion of the tumor so that the entire tumor can be removed through the chest. Dumbbell tumors are prone to cause symptoms due to pressure on the cord or nerve roots and may be anticipated because of the neurologic findings. Horner's syndrome often occurs in association with ganglioneuromas lying in the apex of the chest and is almost certain to follow the operative removal of tumors in that location.

Because of the tendency of the neurogenic tumors to grow to large size and because they show a high incidence of malignant degeneration, they should be removed. Lipomas infrequently develop within the mediastinum but may grow to very large size. When not of excessive size, they are easily dissected out. They should be removed. Malignant mediastinal tumors usually are inoperable, but occasionally they are found early or are sufficiently well circumscribed to justify their removal. To restate briefly: Most operable mediastinal tumors may be removed through standard thoracotomy incisions, the approach usually corresponding to the position of the tumor. Since, however, many important structures are encountered, adequate exposure and careful dissection are essential. If in doubt whether to enter the thorax through an anterior or posterolateral incision, the latter approach had best be used since it gives a more complete exposure.

THYMECTOMY FOR MYASTHENIA GRAVIS

There is a wide divergence of opinion in regard to the effects of thymectomy for myasthenia gravis, in spite of the fact that, since Blalock's report of his first successful case, many patients with myasthenia gravis have been subjected to thymectomy in a number of clinics in this country and in Europe. It is generally conceded that the operation is unjustifiable in the milder cases in which a satisfactory response is obtained from the oral administration of moderate doses of Prostigmin. A number of observers believe that it is unwise to perform thymectomy in very severe cases and recommend waiting for a remission, because very severe myasthenia patients do not withstand surgery well. Keynes, however, believes the operation should be done in those patients whose symptoms grow progressively worse but advises against thymectomy in patients with myasthenia who also have thymic tumors.

Getting these patients in the best possible nutritional state is essential. Prostigmin is given preoperatively and, in some clinics, in very dilute solution intravenously throughout the operation. Intratracheal anesthesia is important and cyclopropane probably is the anesthetic of choice. Curare and Pentothal Sodium should be avoided.

Clagett recommends the sternal-splitting approach except in large tumors, when he uses the posterolateral approach He calls attention to the anatomical

CHAPTER 37

PHARYNX AND CERVICAL ESOPHAGUS

FRANK PHILIP COLEMAN

Occasionally it is necessary to have access to the pharynx from the neck, and this may be obtained by an incision above and parallel to the hyoid bone. The submaxillary gland is retracted and the digastric muscle is identified and preserved. Other muscles of the neck, the mylohyoid, geniohyoid, and hyoglossus, are divided transversely and the posterior part of the tongue is pulled into the wound by a sharp retractor or a traction suture. The pharynx may also be entered by an incision below and parallel to the hyoid bone. The thyrohyoid membrane is divided below the hyoid bone, but sufficient margin should be left attached to the bone to hold sutures. The mucosa is divided, care being taken to avoid injury to the epiglottis. Sutures in the mucosa along the edge of the wound are used as retractors, and a traction suture may also be inserted into the epiglottis. The wound is closed by uniting the mucous membrane, the thyrohyoid membrane, and the muscles in layers with interrupted sutures of fine catgut. A small drain is inserted between the interrupted sutures in the muscle but should not come in contact with the suture line in the mucous membrane.

Exposure of the cervical esophagus may be necessary for the repair of perforations, the removal of neoplasms or foreign bodies, and in the treatment of pharyngoesophageal diverticula. An incision is made usually on the left side, beginning at the level of the hyoid bone and extending down along the anterior border of the sternocleidomastoid muscle to a point one fingerbreadth above the clavicle (Fig. 426). The deep cervical fascia is divided, exposing the cleft between the sternohyoid and omohyoid muscles mesially and the sternocleidomastoid muscle laterally. It may be necessary to ligate and divide the external jugular vein. The omohyoid muscle is divided or retracted and the middle thyroid vein is divided between ligatures. The thyroid gland, trachea, and the lower portion of the larynx are retracted to the right, and the common carotid artery, internal jugular vein, and vagus nerve are retracted laterally, to expose the esophagus (Fig. 426). The recurrent laryngeal nerve is avoided by making an incision in the fascia over the esophagus away from the tracheoesophageal groove. At the completion of the operation the incised wound in the esophagus or the wound resulting from instrumental perforation is closed in layers. The mucosa is approximated by interrupted sutures of fine silk which are tied so that the knots will be inside the lumen, and they must not be tied too tightly. A second row of interrupted sutures of fine silk should be used to approximate the muscular layer. The rest of the wound is closed loosely and a cigarette drain is placed alongside the left lobe of the thyroid gland,

Lee and Blalock and his associates found that ligation of the thoracic duct did not produce chylothorax, but Blalock found that obstruction of the superior vena cava produced chylothorax in about 50 per cent of his animals. Ehrenhaft and Meyers report a case in which the duct was inadvertently divided during a splanchnicectomy. Both ends of the duct were ligated with silk, and the distal segment became distended to a diameter somewhat larger than a lead pencil but did not leak. This patient made an uneventful recovery. Baldridge and Lewis report a patient in whom the upper portion of the cisterna chyli was injured during a secondary sympathectomy for hypertension. The injury was unrecognized at the time and the patient belatedly developed a chylothorax. Transthoracic exploration showed chyle coming through the diaphragm, so the diaphragm was opened and the first part of the thoracic duct and all other lymphatic ducts in that immediate area were ligated. The patient recovered. This case is of especial interest in view of the extensive ligation of important lymphatic trunks. The authors make a strong case for direct surgical attack and ligation of the duct.

In 1898 Cushing accidentally injured the thoracic duct near its junction with the subclavian vein. The duct was repaired and the patient made an uneventful recovery. In 1916 Harrison reported an instance in which he had accidentally divided the thoracic duct in the neck. The proximal end of the duct was anastomosed with the external jugular vein, end to end, with complete recovery. Hodge and Bridges successfully anastomosed the duct to the azygos vein in experimental animals and also in one clinical case.

Procedures by which the continuity of the duct is maintained appeal to one as being more ideal than ligation, but such procedures are more time-consuming than ligation, an undesirable feature in many patients with chylothorax because they so frequently are in a poor nutritional state. It would seem, however, that in case of duct injury which occurs during surgery and is recognized at the time, either end-to-end suture or anastomosis with a vein, usually the azygos, would be desirable.

The thoracic portion of the duct may be exposed either extrapleurally or transpleurally, but transpleural exposure usually will be much simpler. The approach should be on the right side below the sixth dorsal vertebra where the duct lies medial to the azygos vein and from the left side above the fifth dorsal vertebra. Exposure of that portion of the duct between the esophagus and aortic arch is difficult, so if chylothorax develops following resection of a tumor of that portion of the esophagus, it may be better to approach the duct through the right chest and ligate it at the level of the sixth dorsal vertebra. This should lead to rapid closure of the fistula.

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vanced in years and most of them are undernourished as the result of prolonged difficulty in swallowing. Not infrequently they have chronic bronchopulmonary infections, the result of repeated aspiration of the foul contents of the sac. Some of them have lung abscesses which must be cleared up before the diverticulum is excised.

Fig. 427.—Area of development of pharyngoesophageal diverticula.

When their condition has improved sufficiently, one has to determine the side best suited for the approach and whether the operation will be done in one or two stages. The incision is usually made on the left, but occasionally the sac deviates to the right and is more readily exposed from that side. Surgeons tend to use either the one-stage or the two-stage operation, to the exclusion of the other, but Harrington believes that there is a place for both operations, and with this we agree. He advises that the very large diverticula, especially those occurring in old and debilitated patients, be operated upon in stages, and that the smaller diverticula, in patients who are better surgical risks, be removed in one operation. This seems reasonable.

Both the one-stage and the two-stage procedures have advantages and disadvantages. It is always desirable to complete an operation in one stage if it does not increase the operative risk. This is true for economic as well as for technical reasons. The second stage of an operation is nearly always more difficult than the

but it is not placed near the site of closure of the esophagus. This prevents potentially infected material from gravitating to the mediastinum. The foot of the bed is elevated for about forty-eight hours, for the same purpose. For feeding, a small Levine tube is inserted into the stomach and left in place for at least five days.

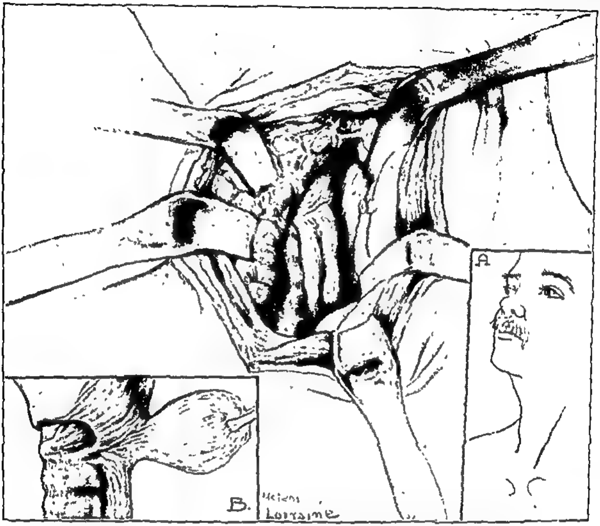


Fig. 426—Exposure of pharyngoesophageal diverticulum through incision over anterior border of sternocleidomastoid muscle The inferior thyroid artery has been doubly ligated and divided.

PHARYNGOESOPHAGEAL DIVERTICULA

Esophageal diverticula may occur from pressure within or from traction without. The latter type, which is usually the result of traction by adhesions, is occasionally formed in the thoracic portion of the esophagus but does not require surgical intervention. Pharyngoesophageal or pulsion diverticula arise between the oblique fibers of the cricopharyngeus muscle on the posterior wall at the junction of the pharynx and esophagus. In these diverticula the sac usually deviates to the left side (Fig. 427) and not infrequently descends into the thoracic cavity. As the sac fills, it presses on the esophagus and interferes with deglutition.

Before patients with pharyngoesophageal diverticula are operated upon, an attempt should be made to get them in good general condition They are often poor candidates for surgery, for a number of reasons: they are usually well ad-

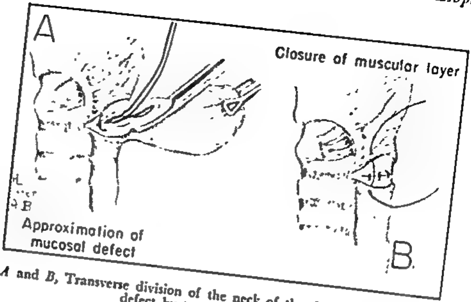


Fig. 428.—*A* and *B*, Transverse division of the neck of the diverticulum with closure of the defect by two layers of sutures.

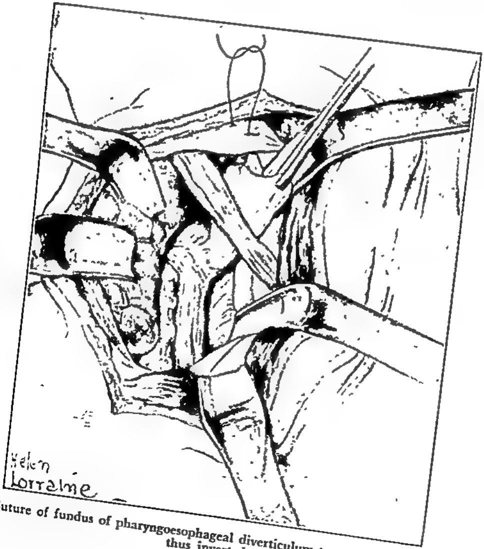


Fig. 429.—Suture of fundus of pharyngoesophageal diverticulum to cervical fascia. The sac is thus inverted.

same procedure would have been at the first operation. Also, at the second ope tion there is greater danger of injury to such important structures as the laryng nerves because of the difficulty in identifying structures and the unsatisfactory section in the presence of tissue reaction. Recurrence of symptoms is more lik after the two-stage operation because closure of the neck of the sac is more diffic and altogether less satisfactory when the tissue is indurated and friable. Exter fistulas also occur more frequently following the two-stage procedure. On t other hand, there is greater danger of mediastinal infection when large sacs removed in one stage. When the diverticulum is complicated by ulceration perforation, a two-stage procedure probably is advisable.

Regional and local infiltration anesthesia have been employed in the majori of our cases, but the few patients who have been subjected to a two-stage operati have been given intratracheal anesthesia for the second stage. Probably the m important advantage of regional and local anesthesia is preservation of the cou reflex, thereby largely avoiding the danger of aspiration of the contents of the s during the manipulation incident to removal of the diverticulum. Also of sor importance is the fact that conscious patients are able to aid in identification of t sac by swallowing when requested to do so.

The patient is placed in the dorsal recumbent position with the shoulde slightly elevated and the head turned to the opposite side. An incision is ma along the anterior border of the sternocleidomastoid muscle from the level of t hyoid bone to the sternum* (Fig. 426, *A*). The deep cervical fascia is incised a the omohyoid muscle is divided at its central tendon. The middle thyroid vein exposed, doubly clamped, and divided, and the carotid artery, jugular vein, a vagus nerve are mobilized and retracted laterally. The inferior thyroid artery carefully exposed by blunt dissection as it passes beneath the common carotid arter at the level of the sixth cervical transverse process, and is doubly clamped, divide and ligated. In this way the thyroid lobe is free so that it can be retracted anterior and medially to expose the fascia overlying the esophagus. The fascia is incised an the diverticulum is exposed by gently retracting the esophagus forward and to th opposite side. If the sac is large, the dissection will extend well into the mediast num. The sac is lifted upward, forward, and laterally, and the adhesions betwee its upper portion and the wall of the esophagus are separated This is done wit great care to avoid opening into the lumen of the esophagus or the sac (Fig. 426, *B*) The adhesions are separated on all sides so that the neck of the sac is completel free. The adhesions on the opposite side of the neck of the diverticulum may b better visualized by rotating the larynx. It is well to remember that the neck o the sac lies at the level of the cricoid cartilage. Lahey stresses the importance o dividing the muscle fibers at the junction of the inferior portion of the neck of th sac with the esophagus The exposure of a zone of submucosa at the junction o the sac with the esophagus is necessary for satisfactory closure, in both the one stage and the two-stage operations. The neck of the diverticulum is divided in plane transverse to the esophagus, and the mucosal defect is approximated by interrupted sutures of fine silk so tied that the knots present within the lumen of the esophagus (Fig. 428). The cricopharyngeal and inferior constrictor muscle fiber above and the uppermost fibers of the esophagus below are approximated by interrupted sutures of fine silk Transverse closure of the defect in the esophagus is

*Bigger recommends a transverse incision, placed in a cervical crease 2.5 to 3.0 cm above the clavicle, and extending from the midline posterolaterally for about 7 or 8 cm

appraise the results. It would seem that carcinoma of the cervical esophagus should be more amenable to surgery than carcinoma of the thoracic esophagus, for in the latter the area of lymphatic spread is very extensive and adjacent essential structures are often involved, whereas the regional lymphatics of the cervical esophagus are limited in extent and there are no absolutely essential structures in the area of direct invasion (Fig. 430). If the hypopharynx, larynx, thyroid gland, or trachea is invaded, it may be resected along with the cervical esophagus. In spite of these favorable anatomical facts, the results from surgery of cancer of the cervical

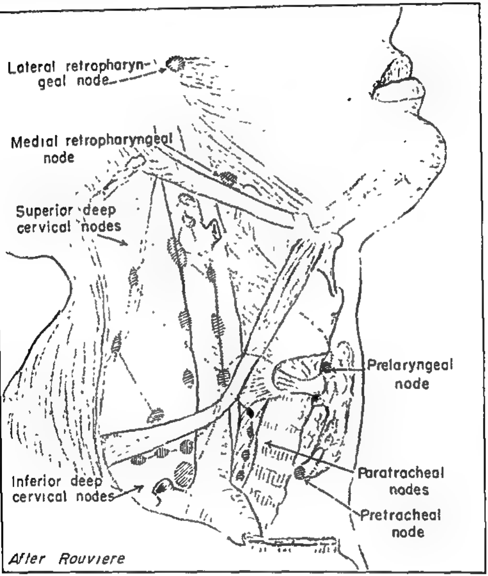


Fig 430.—Regional lymphatic drainage of cervical portion of the esophagus and laryngopharynx.

esophagus are not good. Recurrence following excision of this part of the esophagus cancer usually can be attributed to incomplete removal of regional lymphatics o unjustifiable conservatism in regard to removal of the larynx or other adjacent ctures.

Extension of carcinoma of the cervical esophagus by the lymphatics usually is ned to the cervical region until late in the disease when retrograde thoracic sion may occur. The paratracheal nodes generally show metastases at the of operation but this involvement usually extends no more than 3 cm. below

more secure and is less apt to lead to narrowing or angulation of the esophagus. A small cigarette drain is placed in the pocket previously occupied by the fundus of the diverticulum, but *it must not be placed near the esophageal suture line.* The deep cervical fascia is approximated by interrupted sutures, preferably of fine silk or cotton. The platysma and skin are also closed with interrupted sutures. Upon completion of the operation, a Levine tube is left in place for a period of one week for feeding. Thereafter, fluids are allowed by mouth and a progressive diet is in order.

The first stage of Lahey's two-stage operation is identical with the procedure just described *up to and including isolation of the neck of the diverticulum.* The sac is then brought out and, if large, is sutured to the skin, with a portion of it protruding above the skin surface. It is important to avoid tension on the sac as this may cause angulation of the esophagus. The fundus of the sac is placed at a higher level than its neck, so that it will remain empty (Fig. 429). If the sac is so small that it cannot be sutured to the skin without tension, it may be sutured to the fascia or to the upper portion of the sternohyoid muscle. This should be done with fine black silk *sutures which do not penetrate the entire thickness of the wall* of the sac. The ends of these sutures are left long and are brought out through the skin incision to aid in identifying the sac at the second stage. A cigarette drain is inserted into the mediastinum, to be removed in four days. The wound is closed with interrupted sutures throughout. Liquids and soft foods are allowed.

The chief danger in the first stage of this operation is unrecognized injury to the wall of the sac, resulting in gross infection of the wound and perhaps of the mediastinum. To avoid this danger the wound should be filled with saline solution and the patient asked to swallow. Small leaks may thus be recognized and repaired. One of the dangers in the second stage is injury to the laryngeal nerves because the changes which take place in the tissue between stages make it difficult to identify structures. · The second stage is generally carried out after eight to ten days, under intratracheal cyclopropane or ether anesthesia. The finger is inserted along the sinus tract formed by the drain, and the wound edges are gradually separated by gentle pressure. The long black silk stitches aid in identification of the sac and thereby facilitate this part of the procedure. When these silk sutures are removed, the diverticulum usually is easily separated from the adjacent tissues. The technic of the second stage depends, to some extent, on the size of the sac. If it is unusually large, that portion projecting above the skin surface may be excised and the mucous membrane dissected away to the junction of the sac with the esophagus. The mucous membrane is excised to within 1 cm. of the esophagus and the remainder is pushed into the esophagus and held there by packing, which is removed at the end of four or five days. If difficulty is encountered in separating the mucous membrane from the submucosa, the surrounding tissues may be separated from the sac, which is then incised above and below to within a short distance of the esophagus. The mucous membrane then is separated from the submucosa, and all except about 1 cm of the wall of the sac is excised. The mucosa is treated as previously described.

CARCINOMA OF THE CERVICAL ESOPHAGUS

Three-quarters of a century have elapsed since Czerny performed the first successful resection of the cervical esophagus for carcinoma; however, too few patients have been treated by surgery to establish uniformity of technic or to accurately

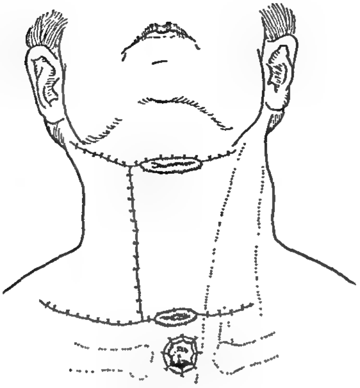


Fig. 431.—Skin flaps for modified Wookey operation permitting radical dissection of neck glands on the right.

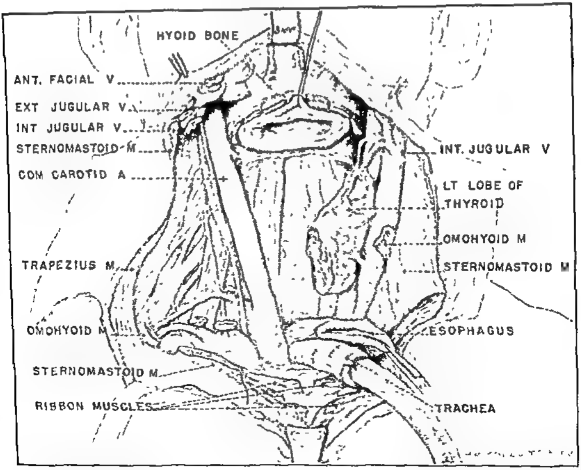


Fig 432.—Block resection of the cervical portion of the esophagus, laryngopharynx, larynx, and trachea Hemithyroidectomy, right side. Radical dissection of neck glands on right, with removal of accessible nodes along left internal jugular vein. (Coleman and Brawner, Arch. Surg.; courtesy American Medical Association)

the primary lesion. Cancer in this area usually spreads first to the paratracheal and superior deep cervical nodes (Fig. 430). The inferior deep cervical nodes usually are involved only by secondary spread from the superior deep cervical group. The fact that cancer of the cervical esophagus not infrequently recurs in the retropharyngeal lymph nodes suggests that these nodes may receive lymphatics directly from the esophagus Adequate removal of the regional lymphatics of the cervical esophagus requires the removal of all lymphatic-bearing tissue from an area extending laterally from the anterior border of one trapezius muscle across to the corresponding muscle on the opposite side, inferiorly to the clavicles and subclavian veins, and superiorly to a line from the mastoid processes along the inferior borders of the mandibles. If bilateral excision of the regional lymphatics is contemplated, it is well to divide the procedure into two stages. If a one-stage procedure is performed, it is important that one internal jugular vein be preserved. *The decision as to which internal jugular vein to preserve is made on the basis of* the extent of nodal involvement.

Carcinoma of the cervical esophagus may be amenable to one of the following *methods of surgical attack:*

1. Block Resection of the Cervical Esophagus, Laryngopharynx, Larynx, Cervical Trachea, and the Regional Lymphatics. Reconstruction of Esophagus by a Skin-Lined Tube

Lesions primary in the postcricoid portion of the esophagus and those lesions arising in other parts of the cervical esophagus but extending to the hypopharynx, larynx, or trachea require this type of excision. This procedure is also indicated in some advanced intrinsic cancers of the larynx, in cancer of the hypopharynx, and occasionally in primary lesions of the trachea with invasion of the esophagus.

The technic described by Wookey is used, but with some modifications. The skin flaps have been altered to permit a simultaneous unilateral neck dissection The primary neck dissection is carried out on the side which shows nodal metastases, or, in the absence of obvious lymph node involvement, the dissection is done on the side on which the primary tumor is predominant. The paratracheal and accessible lymph nodes along the internal jugular vein also are removed on the contralateral side. When cancer of the cervical esophagus invades the thyroid gland, great care is necessary in order to preserve the parathyroid glands and their blood supply.

Intratracheal gas, oxygen, ether anesthesia is administered during the first part of the operation. The exposure is secured by turning back two rectangular flaps of skin, subcutaneous fat, and platysma. A short flap is elevated on the side of the proposed neck dissection; the anterior border of the trepezius muscle is exposed. The skin flap on the opposite side is reflected laterally to the sternocleidomastoid muscle, exposing inferiorly the insertion of this muscle (Fig. 431). The two skin flaps are covered by large pads saturated with saline. Both the sternal and clavicular attachments of the sternocleidomastoid muscle are divided on the side of the neck dissection, while only the sternal attachment is divided on the contralateral side. The insertions of the sternothyroid and sternohyoid muscles are divided close to the manubrium, and these muscles are reflected upward, exposing the thyroid gland. The thyroid isthmus is severed and the lobes are reflected laterally. The

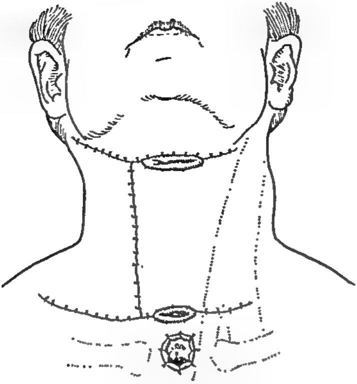


Fig. 431.—Skin flaps for modified Wookey operation permitting radical dissection of neck glands on the right.

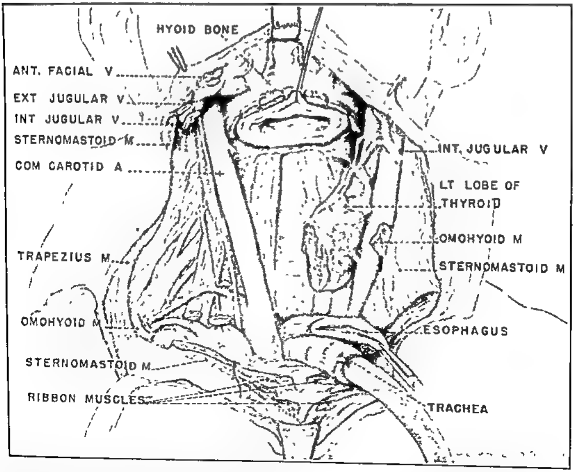


Fig 432.—Block resection of the cervical portion of the esophagus, laryngopharynx, larynx, and trachea Hemithyroidectomy, right side Radical dissection of neck glands on right, with removal of accessible nodes along left internal jugular vein. (Coleman and Brawner, Arch. Surg.; courtesy American Medical Association.)

superior and inferior thyroid vessels and the middle thyroid vein are divided on the side of the neck dissection and the lobe is left attached to the trachea. The blood supply of the contralateral lobe is carefully preserved during its mobilization. The neck dissection is next carried out, removing the jugular vein and the sternocleidomastoid muscle. The entire mass of lymphatic-bearing tissue is dissected from the trapezius muscle toward the larynx. The trachea is freed and the intratracheal tube is removed. The trachea is amputated, and a sterile tube fitted with an inflatable cuff is placed in the distal segment and intratracheal anesthesia is thus continued. (Fig. 432.) The larynx is packed from below with dry gauze. The esophagus is mobilized and a tape is passed around it. The retropharyngeal space is now developed; separating the pharynx from the prevertebral fascia. The pharynx is entered through the thyrohyoid membrane, and unsuspected extension of the lesion upward may necessitate removal of the hyoid bone. The mucous membrane overlying the epiglottis is preserved, but the epiglottis itself is removed with the larynx. The mucosa of the hypopharynx is amputated at least 3 cm. above the tumor. Stay sutures are used to prevent retraction of the pharyngeal mucosa. The esophagus is further mobilized and is amputated 3 cm. or more below the lower margin of the tumor. The mass of tissue including the hypopharynx, the larynx, half of the thyroid gland, the cervical esophagus, the upper portion of the trachea, the sternomastoid muscle, the jugular vein, and the mass of lymphatic-bearing tissue are removed en bloc (Fig. 432). After careful hemostasis, the skin flaps are placed across the prevertebral space. The longer flap is sutured to the prevertebral fascia by two vertical rows of interrupted sutures of 0 chromic catgut. The trachea is brought out through a stab wound in the suprasternal notch and is reamputated; its free edge is approximated to the skin with interrupted sutures of fine silk (Fig. 431). The esophageal stoma is established by suturing the cut end of the esophagus to the skin flap above and to the free edge of the skin incision below. The pharyngeal stoma is established in a similar manner (Fig. 431). A Levine tube is introduced through the esophageal stoma into the stomach for feeding.

After a period of approximately six weeks, when the wounds are well healed and revascularization of the skin flaps has occurred, reestablishment of esophageal continuity is warranted. Between stages, stricture of the esophageal stoma is prevented by periodic digital dilatation. The cervical esophagus is reconstructed as a skin-lined tube after the method of Stevenson (Fig. 433). A large rectangular area devoid of skin is created by formation of the new esophagus and this surface is covered immediately with split thickness grafts. The development of minute fistulas along the suture line of the skin tube may require subsequent minor plastic procedures.

The cosmetic results following this operation are good, and swallowing function is surprisingly good (Fig. 434).

2. Segmental Resection of Cervical Esophagus and Regional Lymphatics. Reconstruction of Esophagus by Skin-Lined Tube

This more conservative operation for carcinoma of the cervical esophagus must be restricted to early lesions. The fact that the tumor frequently extends beyond the wall of the esophagus has led to the infrequent use of this procedure.

The question as to whether or not the tumor can be resected with an adequate margin without sacrificing the larynx can be determined only by exploration.

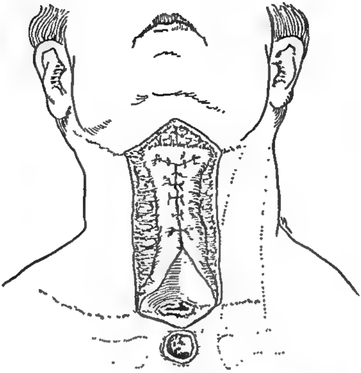
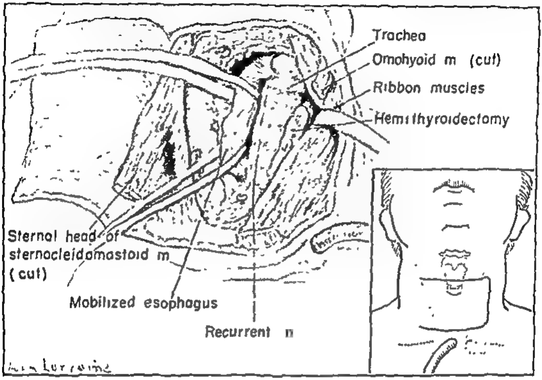


Fig. 433.—Skin tube reconstruction of cervical portion of esophagus.

Fig 434.—Appearance of patient subjected to modified Wookey operation, and skin tube reconstruction of cervical portion of esophagus. (Coleman and Brawner, Arch Surg ; courtesy American Medical Association.)

Preliminary tracheotomy is advisable because manipulation of the esophagus and larynx may cause laryngeal edema or there may be injury to the recurrent laryngeal nerves.

A *single rectangular flap, including the skin and platysma, is elevated* on the side of greater tumor prominence. The sternal head of the sternocleidomastoid



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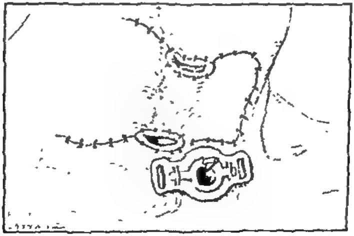

B.

Fig. 435—*A*, Exposure of early carcinoma of cervical esophagus following elevation of rectangular skin flap and right hemithyroidectomy. *B*, Segmental excision of early carcinoma of cervical esophagus with suture of stomata to skin flaps.

muscle is cut and retracted laterally. The superior and inferior thyroid arteries and middle thyroid vein are divided and a hemithyroidectomy is performed before exposing the esophagus The esophagus is mobilized and freed from the trachea and larynx for 4 cm above the tumor and for the same distance below the tumor (Fig.

435). The recurrent laryngeal nerves are carefully preserved during mobilization of the esophagus. According to Watson and Pool, the operation may be completed by one of two methods. The lesion may be exteriorized by suturing a Padgett skin graft behind it, then resecting the involved segment of esophagus several days later. However, immediate resection of the esophagus with suture of the superior and inferior stomata to the skin flaps seems more satisfactory (Fig. 435). The cervical esophagus is reconstructed by means of a skin-lined tube (Fig. 433).

3. Cervicothoracic Resection of the Esophagus With Pharyngogastric or Cervical Esophagogastric Anastomosis

Cancer of the cervical esophagus located at the level of the suprasternal notch is not apt to be amenable to excision by the two previously described operations, for it usually is impossible to establish a cervical esophageal stoma after amputating the esophagus a safe distance below the tumor. Resection of these low-lying cervical esophageal tumors leaves a short proximal stump which is not adaptable to the multistage Torek operation.

Cervicothoracic resection of the esophagus with pharyngogastric or cervical esophagogastric anastomosis has been found feasible in the treatment of supra-aortic intrathoracic cancer of the gullet. The magnitude of the procedure may preclude the performance of a simultaneous neck dissection, but further experience may indicate that it is advisable to remove the regional lymphatics at a later date. On the other hand, if the regional lymph nodes are not removed at the time of cervical esophagectomy, the operation may be followed by dissemination of the cancer. These difficulties probably will limit the application of this procedure to lesions of the esophagus at the thoracic inlet.

For a discussion of the technic, see the section on carcinoma of the supra-aortic portion of the thoracic esophagus, Chapter 38.

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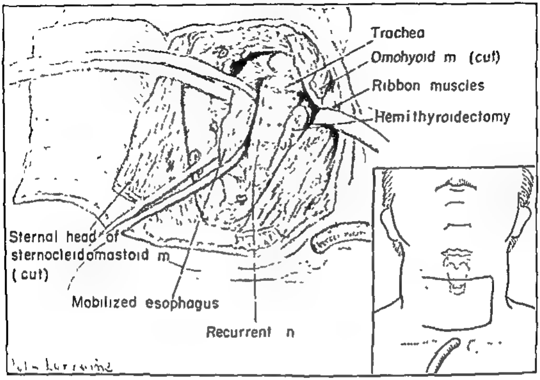

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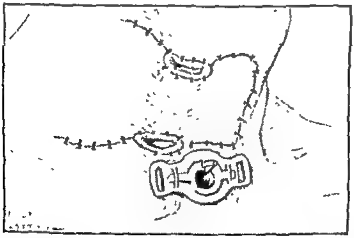

B.

Fig. 435.—*A,* Exposure of early carcinoma of cervical esophagus following elevation of rectangular skin flap and right hemithyroidectomy. *B,* Segmental excision of early carcinoma of cervical esophagus with suture of stomata to skin flaps.

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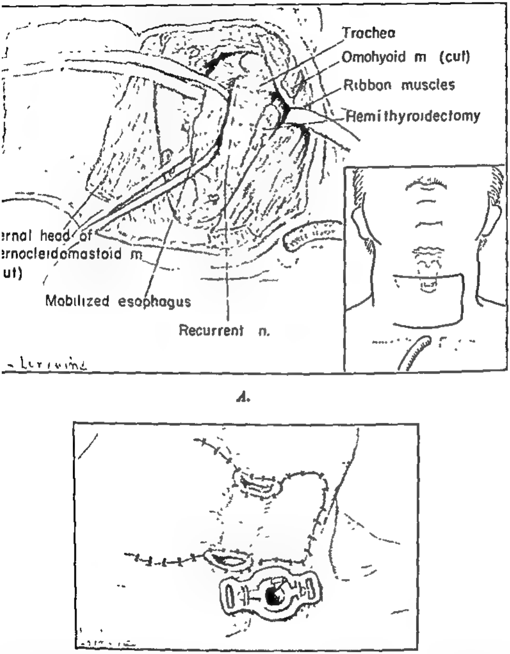

A.

B.

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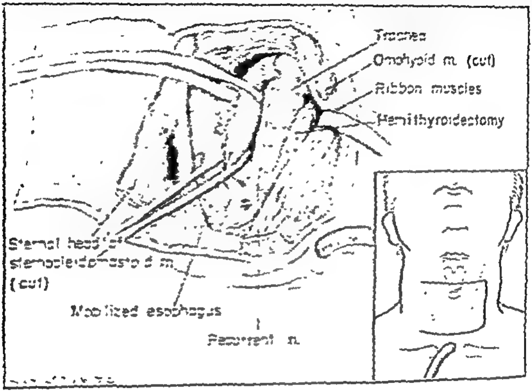

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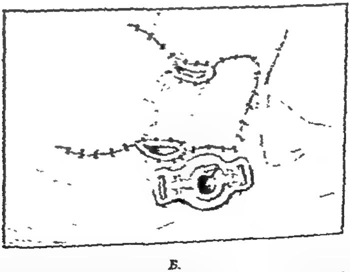

B.

Fig. 455.—*A*, Exposure of early carcinoma of cervical esophagus following elevation of rectangular skin flap and right hemithyroidectomy. *B*, Segmental excision of early carcinoma of cervical esophagus with suture of stomata to skin flaps.

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3. Cervicothoracic Resection of the Esophagus With Pharyngogastric or Cervical Esophagogastric Anastomosis

Cancer of the cervical esophagus located at the level of the suprasternal notch is not apt to be amenable to excision by the two previously described operations, for it usually is impossible to establish a cervical esophageal stoma after amputating the esophagus a safe distance below the tumor. Resection of these low-lying cervical esophageal tumors leaves a short proximal stump which is not adaptable to the multistage Torek operation.

Cervicothoracic resection of the esophagus with pharyngogastric or cervical esophagogastric anastomosis has been found feasible in the treatment of supra-aortic intrathoracic cancer of the gullet. The magnitude of the procedure may preclude the performance of a simultaneous neck dissection, but further experience may indicate that it is advisable to remove the regional lymphatics at a later date. On the other hand, if the regional lymph nodes are not removed at the time of cervical esophagectomy, the operation may be followed by dissemination of the cancer. These difficulties probably will limit the application of this procedure to lesions of the esophagus at the thoracic inlet.

For a discussion of the technic, see the section on carcinoma of the supra-aortic portion of the thoracic esophagus, Chapter 38.

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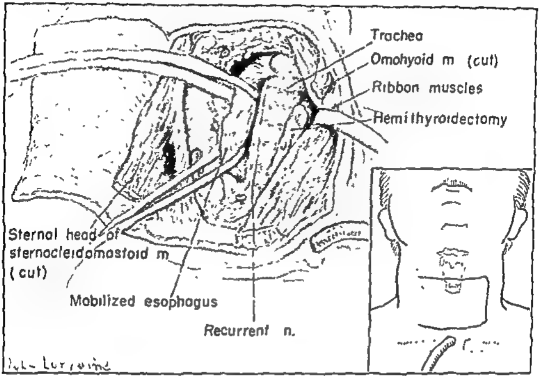
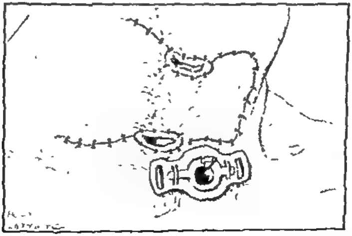
Preliminary tracheotomy is advisable because manipulation of the esophagus and larynx may cause laryngeal edema or there may be injury to the recurrent laryngeal nerves.

A single rectangular flap, including the skin and platysma, is elevated on the side of greater tumor prominence. The sternal head of the sternocleidomastoid



A.



B.

Fig. 435.—*A,* Exposure of early carcinoma of cervical esophagus following elevation of rectangular skin flap and right hemithyroidectomy. *B,* Segmental excision of early carcinoma of cervical esophagus with suture of stomata to skin flaps.

muscle is cut and retracted laterally The superior and inferior thyroid arteries and middle thyroid vein are divided and a hemithyroidectomy is performed before exposing the esophagus The esophagus is mobilized and freed from the trachea and larynx for 4 cm above the tumor and for the same distance below the tumor (Fig.

435). The recurrent laryngeal nerves are carefully preserved during mobilization of the esophagus. According to Watson and Pool, the operation may be completed by one of two methods. The lesion may be exteriorized by suturing a Padgett skin graft behind it, then resecting the involved segment of esophagus several days later. However, immediate resection of the esophagus with suture of the superior and inferior stomata to the skin flaps seems more satisfactory (Fig. 435). The cervical esophagus is reconstructed by means of a skin-lined tube (Fig. 433).

3. Cervicothoracic Resection of the Esophagus With Pharyngogastric or Cervical Esophagogastric Anastomosis

Cancer of the cervical esophagus located at the level of the suprasternal notch is not apt to be amenable to excision by the two previously described operations, for it usually is impossible to establish a cervical esophageal stoma after amputating the esophagus a safe distance below the tumor. Resection of these low-lying cervical esophageal tumors leaves a short proximal stump which is not adaptable to the multistage Torek operation.

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CHAPTER 38

THORACIC ESOPHAGUS

Frank Philip Coleman

*Advances in surgery of the thoracic esophagus may be attributed to the in*creased knowledge of physiology and anatomy of the thoracic viscera, to positive pressure anesthesia and antibiotics, to the use of blood and its substitutes, and to improvements in surgical technic. Although the esophagus is deeply situated in the posterior mediastinum and lies in close contact with many important, even vital structures, it can be approached with relative ease and a satisfactory degree of safety. The esophagus is made up of mucosa, submucosa, and two muscular layers arranged as circular and longitudinal fibers. The longitudinal muscular coat is the predominant one and it does not hold sutures well. The submucosa is weaker here than in the remainder of the gastrointestinal tract, and the lack of a serous coat requires meticulous care in the anastomosis of this organ to other structures. Avoidance of the use of clamps, cautery or caustics, accurate approximation of the mucosa and muscular coats of the gullet to the respective layers of other organs, establishment of esophageal anatomoses without tension, and preservation of the blood supply to the esophagus are technical factors which lead to satisfactory healing.

The blood supply to the esophagus is segmental and forms an arterial pattern similar to that found in the colon or small bowel. The inferior thyroid artery and branches of the subclavian artery supply the cervical portion as well as the intrathoracic portion of the esophagus to a level 2.5 cm. above the bifurcation of the trachea. The remaining portion of the thoracic esophagus is supplied by esophageal arteries which arise from the thoracic aorta and from the bronchial or intercostal arteries. The intra-abdominal portion of the esophagus receives its blood supply from the left gastric, left inferior phrenic, and occasionally from accessory hepatic arteries.

Exposure of the thoracic esophagus formerly was occasionally indicated for the removal of foreign bodies, but with the remarkable development in endoscopy, this indication has become extremely rare.

Perforation of the esophagus is an indication for immediate operation. If the pleura has been injured, a transpleural approach should be made on the side of pleural injury; otherwise, the esophagus should be exposed by the posterior extrapleural mediastinal approach Unless there is a special indication for doing otherwise, it is probably better to make a right-sided approach when the lesion is above the sixth dorsal spine and a left-sided approach when it is below this level. The wound in the esophagus is carefully closed, drainage is established, and the chest wall incision is approximated in layers by well-spaced interrupted sutures.

In perforation of the first portion of the thoracic esophagus, the suprasternal approach may be used and the esophagus pulled upward sufficiently to gain exposure for the repair. If perforation occurs in that portion of the esophagus just above the diaphragm and it is diagnosed immediately, the point of injury may be exposed through an upper left paramedian abdominal incision. When the transabdominal approach is used, the esophagus is separated from the margins of the diaphragmatic opening and pulled down sufficiently for the repair. Under such circumstances, it is wise to do a gastrostomy for temporary feeding. If the diagnosis of such an injury is not made until infection has developed, the approach should not be made through the abdomen.

CARDIOSPASM

The term "cardiospasm" has been used to identify functional obstruction of the lower esophagus since Mikulicz first postulated that it was a result of spasm of the cardia. The underlying alteration of the normal motor mechanism of the esophagus leading to functional obstruction by increased tonus or by inability of a peristaltic wave to pass over a narrow segment of the esophagus is not too well understood. The effects of emotional instability have been emphasized by many as a causative factor. According to Cardenal, Zaaijer, and others, the obstruction is not due to spasm, but to a disturbance of the opening reflex of the cardia. Hurst proposed the name "achalasia" instead of cardiospasm and believed that the difficulty results from a failure of the segment of the esophagus just above the cardia to relax when a wave of peristalsis reaches it. Failure of relaxation of this narrow zone of the esophagus was attributed to degeneration or failure of development of the ganglion cells in Auerbach's plexus. This concept of the physiologic disturbance in cardiospasm, which is similar to that described in connection with Hirschsprung's disease, at this time seems to be the most plausible explanation.

Cardiospasm is characterized by a narrowed segment of the esophagus which is situated just proximal to the cardia. The contracted segment may involve from 3 to [illegible] cm. of the terminal esophagus and usually measures from 0.5 to 1 cm. in diameter. The esophageal wall of this narrow zone may be thin but otherwise is normal in appearance. Associated esophagitis, ulceration, or organic stenosis is not infrequently encountered in the region of the obstruction. There is dilatation of the esophagus above the obstruction. The muscular wall of the esophagus may undergo hypertrophy and the organ often becomes so dilated that it curves upon itself and assumes a more or less tortuous course through the mediastinum. The wall of the dilated portion of the esophagus is thick and the mucosa may become ulcerated as a result of retention of food. A large quantity of food or liquid may accumulate in the esophagus.

Roentgenologic examination is one of the most satisfactory methods for diagnosing cardiospasm. The obstruction is smooth, somewhat cigar-shaped at the cardia, with angulation and wide dilatation of the esophagus above.

The majority of patients with cardiospasm can be successfully treated by conservative measures, but treatment directed only toward the relief of the associated esophagitis is ineffectual. Relief of the obstruction is essential, and probably the most satisfactory method of dilatation is that practiced by Vinson. Attempts at dilatation by the passage of small sounds, bougies, and stomach tubes rarely give

any relief, certainly no permanent relief. According to Vinson, the passage of a No 60F bougie will relieve 10 per cent of these patients of their symptoms, but the most desirable results are accomplished by means of the Plummer or Russell hydrostatic dilators.

The patient is instructed to swallow five yards of size D buttonhole silk thread to guide the dilator into the stomach. The patient begins to swallow the thread twenty-four hours before the time set for the dilatation, swallowing about a foot an hour. If it is swallowed too rapidly the thread tends to accumulate in the esophagus where it tangles and makes instrumentation impossible. Some patients experience difficulty in swallowing the thread, but with perseverance, the great majority of them are successful. Once the silk thread has passed the obstruction, it enters the stomach, then the duodenum and jejunum. After it has passed along several loops of small bowel it is anchored and may be pulled taut. No food is given for twenty-four hours before the dilatation. Anesthesia, local or general, is unnecessary. Before passing the dilator a plain olive bougie (No. 41F) is introduced into the stomach over the thread in order to be certain that the obstruction is not caused by an organic stricture and also to determine whether or not the thread is tangled. The distance from the incisor teeth to the cardia is estimated by this bougie. The introduction of the sound usually causes sufficient regurgitation to empty the esophagus of material retained from the previous day. The dilating instrument is then passed to the cardia over the thread with the right hand, while the thread is held loosely in the left hand. An elastic resistance is encountered at the cardia, but upon drawing the thread taut and applying light pressure to the dilator, the obstruction is felt to relax and the dilator enters the stomach. The dilator is introduced 5 cm. into the stomach and is then gradually distended with water under pressure of 22 to 24 feet. Water, because of its relative incompressibility, is safer for this purpose than is air The pressure is maintained for ten seconds, then is released, and the dilator is withdrawn.

The amount of stretching depends upon the size of the silk bag in which the dilator is enclosed. As pressure is applied, the dilator may tend to pull into the stomach or into the esophagus If this occurs, the dilator is passed into the stomach, filled with water, and then pulled up against the cardia until there is sufficient relaxation to permit 5 to 7.5 cm of the dilator to be drawn into the esophagus The pressure is then further increased

This procedure is necessarily accompanied by considerable trauma There is usually pain in the epigastrium during the dilatation, and there may be slight bleeding. The pain tends to subside in a few minutes but may recur within the next thirty-six hours. An injection of morphine should relieve this pain, but usually there is some soreness in the epigastric region for several days The patient is kept in the hospital for one or two days and is given as liberal a diet as he can take comfortably. However, if there is severe pain, oral feeding is withheld and fluids are administered by vein or by hypodermoclysis.

The patient is carefully observed for approximately one week, when the dilatation should be repeated if there is persistent obstruction.

According to Vinson, 75 per cent of patients suffering from cardiospasm can be cured by a single dilatation when the Russell dilator is used as described. Another 20 per cent can be cured by repeating the dilatation, while 5 per cent cannot

be cured by dilatation but can be made more comfortable. If there is recurrence, the symptoms almost always appear within six months after the treatment.

The irritation of the esophagus caused by retention and decomposition of food may be treated by having the patient wash out the esophagus with considerable quantities of water or by lavage. Atropine is of no benefit in this condition and may even increase the obstruction. If hydrostatic dilatation fails to give satisfactory results, operation may be indicated.

Surgery is most definitely indicated in those cases of cardiospasm in which there is associated or secondary fibrous stenosis, for obstruction will recur in these patients even after repeated dilatations. Various operative procedures have been proposed, such as resection of the narrowed segment with reanastomosis, cardioplasty, lateral esophagogastric anastomosis, and longitudinal incision of the muscular coats overlying the narrowed segment of esophagus.

In selected cases, cardioplasty, patterned after the method described by Finney for pyloric stenosis, has given satisfactory results. However, to achieve satisfactory results it may be necessary to anastomose at least 10 cm. of the lower esophagus to the fundus of the stomach.

Organic strictures or extensive ulceration of the terminal esophagus associated with cardiospasm require resection of the lower esophagus and anastomosis of the dilated proximal segment to the fundus of the stomach. The technic for this operation will be described later in connection with resection of the terminal esophagus for carcinoma. When resection is done for benign strictures, the vagus nerves are retracted and preserved.

It is well to remember that resection of the cardia and lower esophagus with esophagogastrostomy may be complicated by the development of marginal ulcers of the esophagus, just above the site of anastomosis. This complication led Womack and others to carry out extensive partial gastrectomy, removing all the acid-bearing portion of the stomach in those patients with normal or increased secretion of hydrochloric acid. The need for extensive gastrectomy will have to be appraised on the basis of greater experience.

The Finney type of cardioplasty for the relief of cardiospasm may be performed through either a transabdominal or a transthoracic approach. The esophagus is usually sufficiently dilated and elongated to permit delivery of 10 to 12 cm. of the lower esophagus into the abdomen after thorough stretching of the hiatus (Fig. 436). However, some prefer the thoracic approach and think it gives a more satisfactory exposure.

When an abdominal [illegible] made (Fig. [illegible] The esophagus is separated from its attachments to the diaphragm by sharp and blunt dissection and then pulled down into the abdominal cavity. This is facilitated by placing a tape around the esophagus and putting traction on the tape (Fig. 436, *B*). If the area of constriction in the esophagus is small and thickened, a simple incision into the serosa and muscular coat with separation of the muscular coat but not of the mucosa may be all that is necessary. This is similar to the Fredet-Ramstedt operation for congenital pyloric stenosis. If the area of constriction is more extensive, a U-shaped incision is made, beginning in the esophagus well above the point of constriction and extending down into the cardiac end of the stomach and then

up into the fundus of the stomach This enlarges the opening and completely divides the muscles about the cardia. Interrupted sutures of catgut or silk are placed first in the serosal coat of the stomach and esophagus (Fig. 436, *C*) to fix the fundus to the esophagus. The mucosae of the esophagus and stomach are then sutured together with either continuous or interrupted silk sutures (Fig. 436, *D* and *E*). This is reinforced with a second row of continuous or interrupted sutures in the muscular coat and the serosa is then sutured with interrupted catgut.

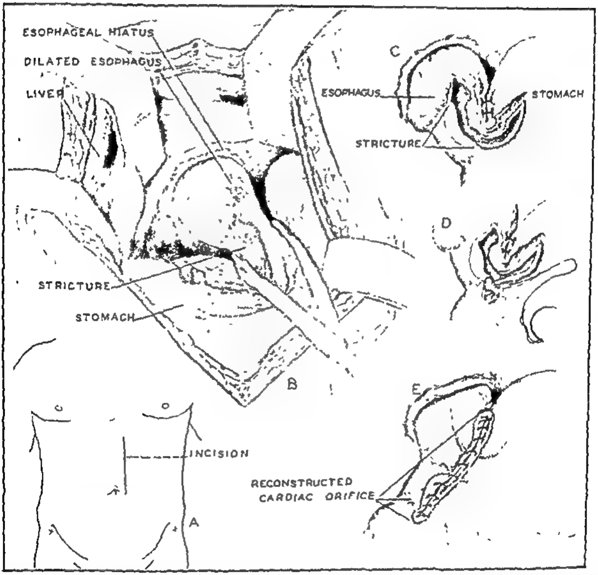


Fig 436.—Cardiospasm repaired through the abdominal approach. *A*, Line of incision in the abdomen *B*, The esophagus has been separated from the diaphragm, a tape placed around the esophagus, and the dilated esophagus brought into view. *C*, The incision extends from the dilated esophagus through the stricture and back into the fundus of the stomach. *D*, The outer surface of the esophagus has been sutured to the serosa of the fundus of the stomach with interrupted sutures and the mucosal stitch is started in the lower angle of the wound *E*, The mucosal and muscular coats have been united and the serosal surface will next be sutured.

For the thoracic approach the incision is made on the left side overlying the ninth rib and the rib is subperiosteally resected A rib spreader is introduced and the lung is pulled upward and mesially. The phrenic nerve is crushed 3 cm. above the diaphragm The mediastinal pleura is incised just anterior to the aorta and

the esophagus is mobilized by sharp and blunt dissection, preserving the vagus nerves and the segmental esophageal arteries. The narrowed segment of the terminal esophagus is identified. The subdiaphragmatic space is entered by making an incision through the central tendon of the diaphragm. The incision may then be extended into the esophageal hiatus under direct vision without danger of injury to the abdominal viscera or the blood supply to the terminal esophagus. The fundus and cardia of the stomach are mobilized by division of the vasa brevia and by dividing the peritoneal reflection from the stomach to the undersurface of the diaphragm.

The fundus of the stomach is brought up and the anterior wall is approximated to the esophagus for a distance of at least 10 cm. with interrupted mattress sutures of four 0 silk. The lumen of the esophagus is obstructed by tape above the superior suture to prevent soiling of the wound. An incision is made through the wall of the esophagus parallel to the suture line. This incision is then carried back through the wall of the stomach paralleling the esophageal incision. Upon opening the lumen of the stomach, it is necessary to obtain complete hemostasis by ligating individually the submucosal vessels. A second layer of interrupted four 0 silk sutures is placed posteriorly through the entire thickness of the walls of the stomach and esophagus, the two mucosal layers being carefully approximated. The first anterior layer is placed in a similar manner and the knots are tied within the lumen. The closure is completed by a second anterior layer of interrupted mattress sutures of four 0 silk. The site of anastomosis may be reinforced by pulling up the omentum from the abdominal cavity. The defect in the diaphragm is closed by interrupted sutures of silk to a point where the stomach wall and esophagus are encountered. A new hiatus is then constructed by anchoring the cut edges of the diaphragm to the walls of the stomach and esophagus with interrupted sutures of fine silk. The left pleural cavity is washed thoroughly with saline solution and the wound is closed in layers after the introduction of anterior and posterior intercostal tubes for drainage of the pleural cavity. The intercostal tubes are removed on the second postoperative day. A progressive diet is allowed.

EPIPHRENIC ESOPHAGEAL DIVERTICULA

Pulsion diverticula developing in the lower one-third of the esophagus are often called epiphrenic diverticula and usually make their appearance 6 to 10 cm. proximal to the cardia of the stomach. They may extend into either the right or the left pleural cavity. The etiology probably is similar to that of pharyngoesophageal pulsion diverticula, since there is a herniation of the mucosa and submucosa through the muscular layers of the esophagus. Epiphrenic diverticula may be associated with cardiospasm or stricture of the terminal esophagus. The clinical symptoms usually are those of cardiospasm, which may be the cause or the result of the diverticulum. Serious malnutrition may result. Inflammation of the diverticulum may occur as the result of the retention of food and may extend through the pleura and into the mediastinum. Roentgenograms following ingestion of barium will establish the diagnosis. Esophagoscopy may be of value.

The most satisfactory surgical treatment for these diverticula in the absence of stricture of the terminal esophagus is excision of the diverticulum and closure of the esophageal defect. When an associated cardiospasm persists after excision of

iverticulum, relief usually can be obtained by hydrostatic dilatation. Lahey :s dissection of the sac and suturing of it in an upside-down position. Excision preferable. *Epiphrenic diverticulum associated with unyielding stenosis of* rminal esophagus requires resection of the diverticulum along with the termi- :ophagus and esophagogastrostomy. The technic is essentially the same as or resection of the terminal esophagus for carcinoma.

'he majority of epiphrenic diverticula are amenable to simple excision with e of the esophageal defect. Peridiverticulitis involving the mediastinal tissues leura may render dissection of the diverticulum so difficult it may be wiser astomose the fundus of the diverticulum to the stomach (diverticulogas- my).

RTICULECTOMY

. Levine tube is introduced into the esophagus and the patient is placed on ght side. The left pleural cavity is entered through the bed of the sub- teally resected eighth rib. The lung is pulled anteriorly and upward and the stinal pleura is incised anterior to the aorta over the lower one-half of the agus. The esophagus is mobilized above and below the diverticulum and ıded with tapes. The diverticulum is then freed from the pleura and the :nt mediastinal tissues. During this dissection, great care should be exercised *vent tearing or cutting into the lumen of the diverticulum. The neck of the* iculum should be completely dissected out. At the junction of the diverticu- 'ith the esophagus it should be possible to identify the submucosa and mucosa ıe muscle wall as two quite distinct layers. The diverticulum is excised by an cal incision directed vertically and the defect in the esophageal lumen is by two layers of interrupted silk sutures as described under resection of ngoesophageal diverticula The mediastinal pleura is closed by interrupted :s of fine silk. The pleural cavity is washed with saline solution and the l is closed in layers, after the introduction of an intercostal tube.

HAGOPLASTY

:ecent advances in surgery of the thoracic esophagus have directed increasing ion to the various methods used to reestablish continuity of the alimentary following esophageal resection. It has been necessary to reevaluate carefully :ed for the tedious and time-consuming process of forming an antethoracic agus. Transpleural esophagogastrostomy has generally proved more satis- y than has construction of an external esophagus. Alterations of the stomach emical burns or by previous surgery or disease may preclude the use of this as a substitute for the esophagus. The jejunum has been used successfully enhoff and others for intrathoracic and transthoracic anastomosis with the esophagus. Rienhoff has demonstrated that this requires a shorter loop of ne, less mobilization, and less interference with the mesenteric circulation is required by the antethoracic, subcutaneous route. Recently, Harrison has d an ingenious two-stage method for transthoracic esophagojejunostomy. The pment of satisfactory methods for transthoracic anastomosis of the stomach ps of bowel with the upper esophagus has well-nigh eliminated the need for uction of the antethoracic esophagus.

Formerly antethoracic esophagoplasty was done by making use of skin tubes, small bowel, or by a combination of skin tube and bowel. The colon and the stomach also were used (Fig. 437). Yudin concluded from his extensive experience that there were two reliable methods for performing antethoracic esophagoplasty: the total intestinal esophagoplasty of the Roux-Herzen type and the combined operations of Wullstein, Lexer, and Blauel. The Roux-Herzen method requires division of the first five vasa recti jejunalis to obtain sufficient length of bowel to reach the pharynx. This may compromise the blood supply to the oral end of the jejunum

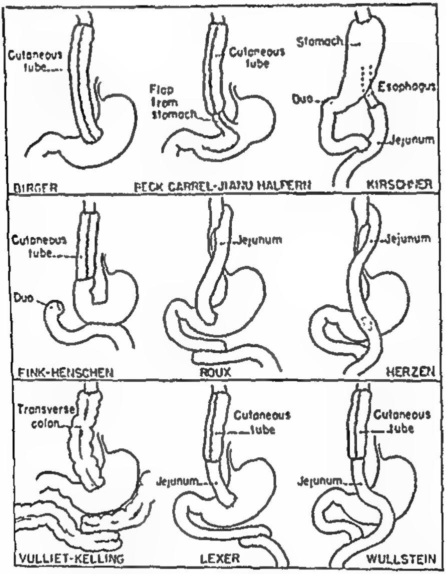


Fig 437.—The various types of antethoracic esophagoplastic operations. (After Yudin, Surg., Gynec & Obst.; courtesy Franklin H. Martin Memorial Foundation.)

which may not be obvious at the time of operation. It would seem that the Roux-Herzen method is chiefly applicable in young individuals with extensive strictures of the esophagus. A short mesentery, excessive fat in the mesentery, and anomalies of the vessels of the mesenteric arcade may make it impossible to mobilize a sufficient length of intestine. Under such circumstances it is wise to abandon total intestinal esophageal substitution and insert the available or mobilizable segment of jejunum into a subcutaneous tunnel which may extend up to the mid-chest or

the diverticulum, relief usually can be obtained by hydrostatic dilatation. Lahey advises dissection of the sac and suturing of it in an upside-down position. Excision seems preferable. Epiphrenic diverticulum associated with unyielding stenosis of the terminal esophagus requires resection of the diverticulum along with the terminal esophagus and esophagogastrostomy. The technic is essentially the same as that for resection of the terminal esophagus for carcinoma.

The majority of epiphrenic diverticula are amenable to simple excision with closure of the esophageal defect. Peridiverticulitis involving the mediastinal tissues and pleura may render dissection of the diverticulum so difficult it may be wiser to anastomose the fundus of the diverticulum to the stomach (diverticulogastrostomy).

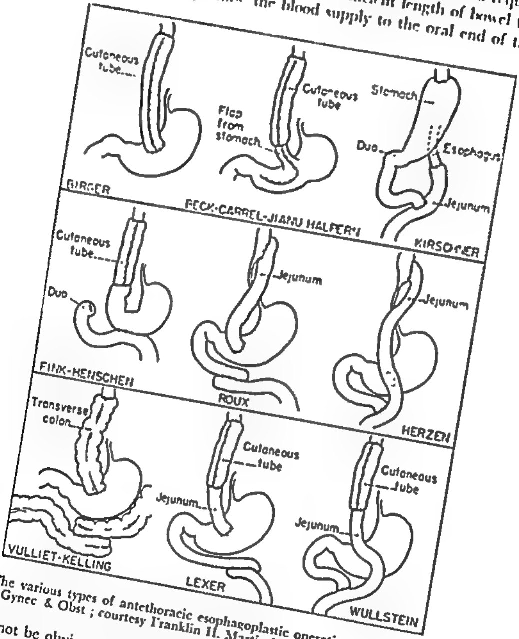
DIVERTICULECTOMY

A Levine tube *is introduced into the esophagus and the patient is placed on* the right side. The left pleural cavity is entered through the bed of the subperiosteally resected eighth rib. The lung is pulled anteriorly and upward and the mediastinal pleura is incised anterior to the aorta over the lower one-half of the *esophagus The esophagus is mobilized* above and below *the diverticulum* and suspended with tapes. The diverticulum is then freed from the pleura and the adjacent mediastinal tissues. During this dissection, great care should be exercised to prevent tearing or cutting into the lumen of the diverticulum. The neck of the diverticulum should be completely dissected out. At the junction of the diverticulum with the esophagus it should be possible to identify the submucosa and mucosa and the muscle wall as two quite distinct layers. The diverticulum is excised by an elliptical incision directed vertically and the defect in the esophageal lumen is closed by two layers of interrupted silk sutures as described under resection of pharyngoesophageal diverticula. The mediastinal pleura is closed by interrupted sutures of fine silk. The pleural cavity is washed with saline solution and the wound is closed in layers, after the introduction of an intercostal tube.

ESOPHAGOPLASTY

Recent advances in surgery of the thoracic esophagus have directed increasing *attention to the various methods used to reestablish continuity of the* alimentary tract following esophageal resection. It has been necessary to reevaluate carefully the need for the tedious and time-consuming process of forming an antethoracic esophagus. Transpleural esophagogastrostomy has generally proved more satisfactory *than has construction of an external esophagus. Alterations of the stomach* by chemical burns or by previous surgery or disease may preclude the use of this organ as a substitute for the esophagus. The jejunum has been used successfully by Rienhoff and others for intrathoracic and transthoracic anastomosis with the upper esophagus. *Rienhoff has demonstrated that this requires a shorter loop of* intestine, less mobilization, and less interference with the mesenteric circulation than is required by the antethoracic, subcutaneous route. Recently, Harrison has devised an ingenious two-stage method for transthoracic esophagojejunostomy. The development of satisfactory methods for transthoracic *anastomosis of the stomach* or loops of bowel with the upper esophagus has well-nigh eliminated the need for construction of the antethoracic esophagus.

Formerly antethoracic esophagoplasty was done by making use of skin tubes, small bowel, or by a combination of skin tube and bowel. The colon and the stomach also were used (Fig. 437). Yudin concluded from his extensive experience that there were two reliable methods for performing antethoracic esophagoplasty: the total intestinal esophagoplasty of the Roux-Herzen type and the combined operations of Wullstein, Lexer, and Blauel. The Roux-Herzen method requires division of the first five vasa recti jejunalis to obtain sufficient length of bowel to reach the pharynx. This may compromise the blood supply to the oral end of the jejunum



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above. The cutaneous tube to connect the pharynx or upper esophagus to the jejunum is constructed later. This is known as the Lexer-Wullstein operation and Ochsner and Owens regard it as the best method for creating an artificial antethoracic esophagus.

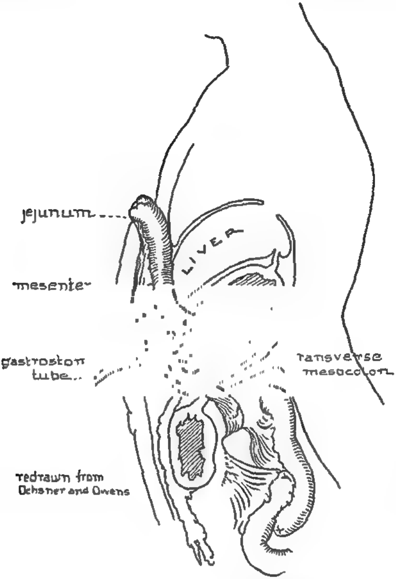

Fig 438.—Diagram showing the production of the jejunal tube. Its mesentery is brought up through the lesser sac This segment of the jejunum is anastomosed with the stomach. Its position beneath the skin of the lower thorax is shown. (After Ochsner and Owens: Tr. Am. S. A., 1934, J. B. Lippincott Co.)

The first stage of this operation is mobilization of the jejunal segment. A loop of jejunum, the upper end of which is about 30 cm. distal to the ligament of Treitz, is isolated. The bowel is doubly clamped and divided, and its mesentery is incised so that it will permit the upper end of the loop to be brought well up onto the chest wall, but no attempt is made to reach the upper end of the esophagus. Great care is taken in dividing the vessels in the mesentery of this loop. They are occluded by digital compression before being divided in order to be certain the blood supply to the loop will not be materially affected by their division. The ends of the jejunum left by isolating this loop are united by an end-to-end or lateral anastomosis and each end of the isolated segment is occluded by purse-string suture. This loop,

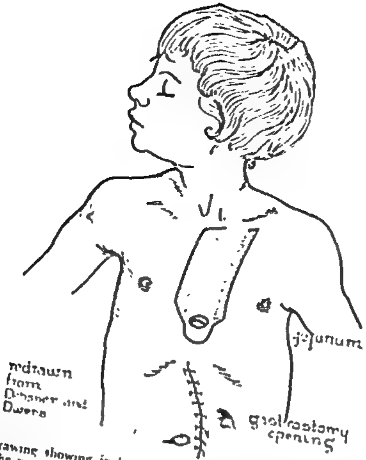

Fig. 439.—Drawing showing incision used in the formation of the tube of skin on the anterior thorax. The portion of the flap on the right is undermined more extensively than on the left. The undermined area is indicated by the stippling. (After Ochsner and Owens: Tr Am. S. A., 1934, J. B Lippincott Co.)

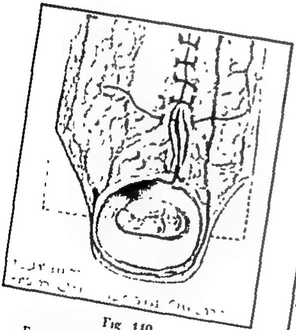

Fig 440

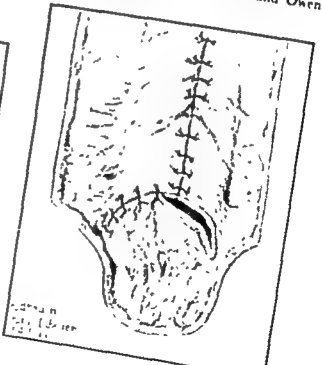

Fig. 441.

Fig 440.—The incision used for the formation of a tube of skin includes a flap of skin below the union of the jejunal loop with the skin. (After Ochsner and Owens: Tr. Am. S A., 1934, J. B Lippincott Co.)

Fig 441.—Drawing showing the manner of approximating the lateral and lower skin flaps All sutures are intradermal (After Ochsner and Owens: Tr. Am S. A., 1934, J. B. Lippincott Co.)

above. The cutaneous tube to connect the pharynx or upper esophagus to the jejunum is constructed later. This is known as the Lexer-Wullstein operation and Ochsner and Owens regard it as the best method for creating an artificial antethoracic esophagus.

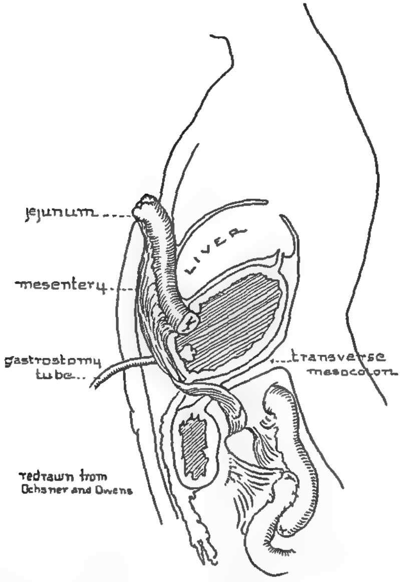

Fig 438 —Diagram showing the production of the jejunal tube. Its mesentery is brought up through the lesser sac. This segment of the jejunum is anastomosed with the stomach Its position beneath the skin of the lower thorax is shown (After Ochsner and Owens: Tr. Am. S. A, 1934, J B Lippincott Co)

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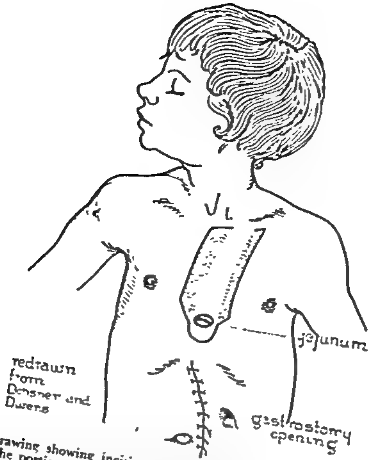

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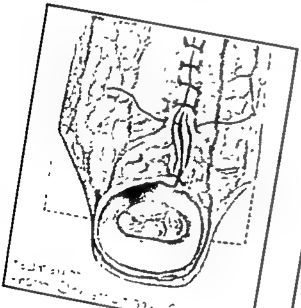


Fig 440

Fig. 441.

Fig 440.—The incision used for the formation of a tube of skin includes a flap of skin below the union of the jejunal loop with the skin. (After Ochsner and Owens: Tr. Am. S. A., 1934, J. B Lippincott Co)

Fig 441 —Drawing showing the manner of approximating the lateral and lower skin flaps. All sutures are intradermal. (After Ochsner and Owens: Tr. Am. S. A., 1934, J. B. Lippincott Co)

whose ample blood supply has been assured by the careful division of the mesentery, is brought through the transverse mesocolon and then through the gastrocolic omentum. The distal end is anastomosed to the stomach. The proximal end is carried through a subcutaneous antethoracic tunnel. A short transverse skin incision is made at a suitable level and the unopened bowel is sutured to the margins of the skin incision. This completes the first stage of the operation (Fig. 438).

The second stage consists of the formation of the connecting skin tube and the union of the lower end of this tube with the jejunum (Fig. 439). The tube is fashioned from the skin over the anterior surface of the thorax. After outlining it by lateral incisions, the lower ends of these incisions are continued downward and inward to surround the open end of the jejunum and to form a flap below it. This flap can be turned upward over the jejunal stoma to join the skin tube. The suture line is placed above the jejunal stoma and care is taken to avoid tension on it. In this way there is less likelihood of the suture line breaking down (Figs. 440 and 441).

Relaxation incisions are made parallel to the incisions outlining the flap. The incisions for the skin tube are 6 cm. apart and extend from the jejunal stoma to the left sternoclavicular articulation. They are undermined for 2.5 cm. on the right side and 1.5 cm. on the left to prevent the anterior suture line falling directly beneath the suture line used to close the skin over the tube. The suturing of the skin tube is done with fine interrupted catgut, two rows being placed, the second row in the subcutaneous tissue. Sutures of silkworm-gut for relaxing the skin which has been approximated over the skin tube are inserted beneath the tube, and buttons are used to fix the ends of these sutures. The relaxation incisions are, of course, external to this row of buttons. It is necessary that the sutures used to approximate the skin over the newly formed tube be tied under as little tension as possible.

After this second stage, sufficient time is permitted for the patient to regain his strength, and in the meantime the mouth and pharynx should be kept carefully cleansed. Of course, before any of these operations are performed, a gastrostomy has been made for feeding since the only indication for the procedure is complete atresia of the esophagus.

In the third stage of the operation, the cervical esophagus is mobilized through an incision which is made along the anterior border of the sternomastoid muscle to a point just above the clavicle, and is then curved laterally along the clavicle. The esophagus is mobilized well into the mediastinum and is doubly clamped with right-angled clamps and divided. The lower end of the esophagus is closed with a basting stitch or with purse-string sutures. The upper end of the previously formed skin tube is separated slightly from the covering skin, and the upper end of the esophagus is invaginated into the upper end of the skin tube. (Fig. 442.)

The esophagus is sutured to the skin tube with interrupted Lembert sutures which invert the freshened margin of the skin tube. The margins of the esophagus have already been invaginated. In this way the sutures are protected from the saliva and the danger of fistula is minimized.

The jejunum, when transplanted into the thorax by Harrison's method, serves as an excellent substitute for the esophagus. The first stage of the operation consists of mobilizing a segment of jejunum of sufficient length to reach the pharynx, care being taken to preserve an adequate blood supply. This procedure can be

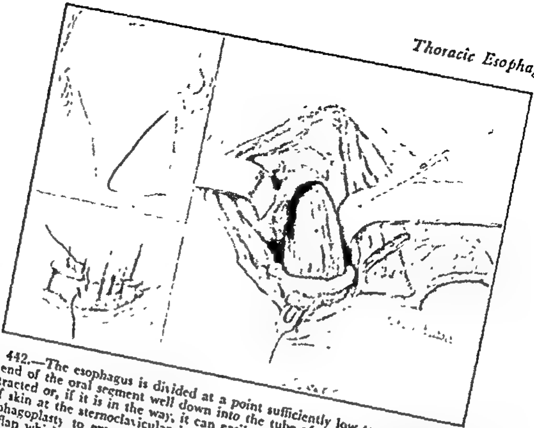


Fig. 442.—The esophagus is divided at a point sufficiently low to permit the insertion of the distal end of the oral segment well down into the tube of skin. The sternomastoid muscle may be retracted or, if it is in the way, it can easily be divided. *a*, Showing the incision to be used in the upper end of the tube of skin at the sternoclavicular junction and the incision to be used in the third stage of the esophagoplasty to expose the esophagus. At its lower end the incision is curved to produce a flap which is used to cover the union of the esophagus with the skin. *b*, Showing the manner in which approximating sutures are inserted through the outer portion of the esophagus and the subcutaneous portion of the tube of skin. The triangular flap of skin is brought over the anastomosis of the esophagus and the skin tube, and the wound is closed. (After Ochsner and Owens: Tr. Am. S. A., 1934, J. B. Lippincott Co.)

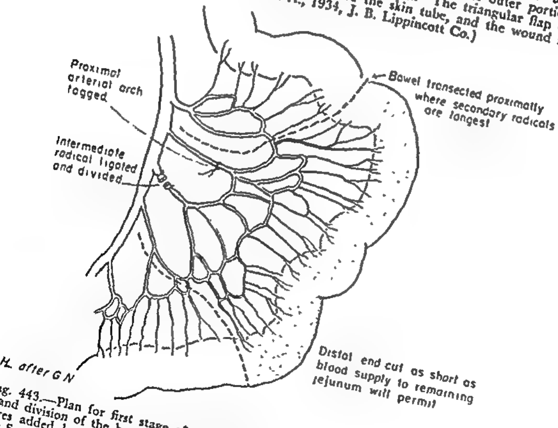


Fig. 443.—Plan for first stage of operation showing the development of a long arterial arcade and division of the bowel at a point where the secondary arterial radicals are longest. This gives added length to the intestine when it is straightened out. (After Harrison, J. Thoracic Surg.; courtesy The C. V. Mosby Co.)

carried out without interference from or with an established gastrostomy. abdomen is opened through an upper transverse or paramedian incision. careful study of the vasa recti of the proximal jejunum, a long arterial arc established by sacrificing one or two intermediate branches (Fig. 443). The is divided proximally where the secondary radicals are longest, for this gives length to the bowel when it is straightened out. The distal end of the jejun divided as close as possible to the inferior border of the long arterial arcade. proximal arterial arcade is tagged with a black silk suture for identification second stage. An incision is made in the transverse mesocolon and the isolate of jejunum is brought up through this and through the gastrohepatic liga The proximal end of the jejunal loop is closed by two layers of sutures a distal end is anastomosed to a circular defect made in the anterior wall c fundus of the stomach. The site of anastomosis and the coiled-up loop are co with the greater omentum. (Fig. 444.) The continuity of the infracolic jej is reestablished by an end-to-end anastomosis.

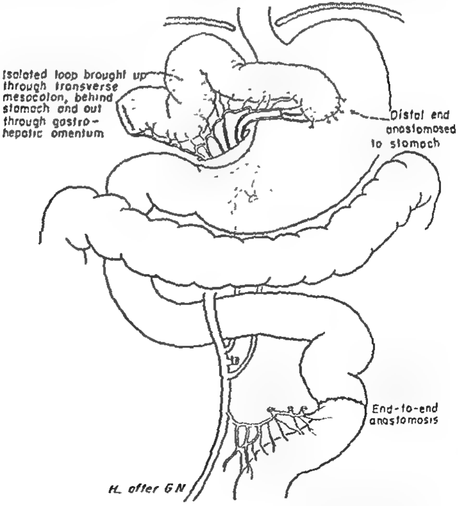
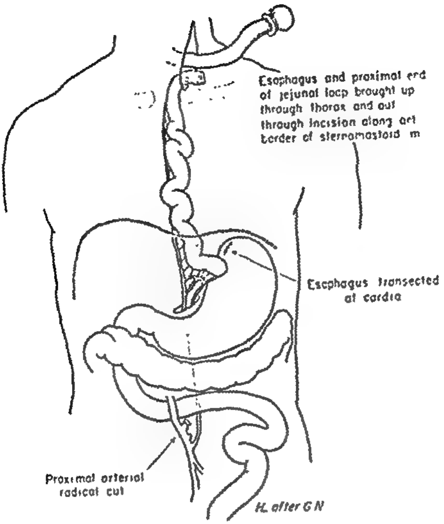
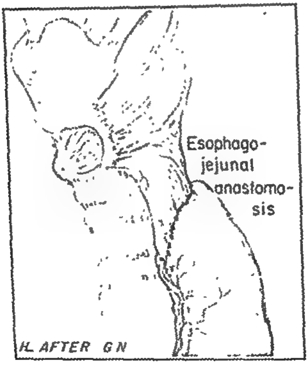


Fig. 444.—First stage completed The proximal arm of the arterial arch is divided a second stage. (After Harrison, J. Thoracic Surg , courtesy The C. V. Mosby Co.)

Ten days to two weeks later the left pleural cavity is entered through the of the subperiosteally resected eighth rib and the pleura overlying the esophag incised. It is usually necessary to divide the seventh, sixth, and fifth ribs just terior to their angles to obtain adequate exposure of the entire esophagus.



A.



B.

Fig 445.—*A*, Second stage completed. *B*, Oblique anastomosis of the esophagus of the transposed jejunal segment. (After Harrison, J. Thoracic Surg ; courtesy The C. V. Mosby Co.)

extent of pathology is determined after partial mobilization of the esophagus. Extensive strictures of the esophagus may be associated with marked fibrosis and fixation of the mediastinal structures, and mobilization of the fibrosed esophagus may prove to be hazardous. In such cases, it seems wise to leave it in situ and proceed with the transplantation of the jejunum into the thorax. An incision is made through the mesial portion of the central tendon of the diaphragm and is extended into the esophageal hiatus. The omentum is carefully freed from the loop of jejunum and the proximal arm of the arterial arch is identified and divided. The peritoneum and the lymph nodes are removed from the mesentery thus freeing the vascular arcade, which permits the jejunal loop to be straightened out. If the esophagus is resected, the vagus nerves are retracted and preserved; the esophagus is divided at the cardia and the opening into the stomach is closed by two layers of sutures. The esophagus is then freed up from below upward and is passed beneath the aortic arch. The supra-aortic esophagus is mobilized and the jejunal loop is passed beneath the arch of the aorta.

An incision is then made from the level of the hyoid bone to the suprasternal notch along the anterior border of the left sternocleidomastoid muscle. The cervical esophagus is mobilized and the entire esophagus is delivered into the neck along with the jejunal loop (Fig. 445, *A*). The jejunal loop is straightened out, but care is used to avoid undue tension which might injure the vascular arcade. The diaphragm is reconstructed about the jejunal loop. The pleural cavity is washed thoroughly with saline solution and the wound is closed in layers after the placement of intercostal drainage tubes.

One to two weeks later the mediastinal space will be found obliterated and the anastomosis between the proximal jejunum and the cervical esophagus or pharynx can be carried out without danger of mediastinitis, even though a fistula should develop. The anastomotic stoma should be made as large as possible and this may be accomplished by a side-to-side anastomosis or by an oblique end-to-end anastomosis. The anastomosis is completed by two layers of interrupted fine silk sutures which are placed in a manner similar to the technic described for esophagogastrostomy (Fig 445, *B*). A small Penrose drain is placed in the retropharyngeal space, but it must not be in close proximity to the anastomosis.

CARCINOMA OF THE THORACIC ESOPHAGUS

Until recent years resection of the thoracic esophagus for carcinoma gave such discouraging results that many physicians felt that such operations were not warranted This attitude is not surprising since in the Torek operation, the one commonly used for a number of years, the esophagus was removed, leaving the patient with a cervical esophagostomy and a gastrostomy. Construction of an antethoracic esophagus was difficult, time-consuming, and generally unsatisfactory. Not infrequently the disease recurred before completion of the multistage esophagoplasty. Resection of the lower esophagus with immediate restoration of continuity to the alimentary tract was achieved by Adams and Phemister in 1938 This significant advance in surgery of the thoracic esophagus was accomplished by elevating the fundus of the stomach into the thorax and anastomosing it to the end of the esophagus. By 1941 this procedure had become well established and was found to be applicable to carcinoma of the cardia as well as to carcinoma of the distal third

of the esophagus. In 1944 Garlock and Sweet, independently, modified the operation of Adams and Phemister and showed that the stomach could be sufficiently mobilized to anastomose it to the esophageal stump following the resection of carcinoma of the esophagus at or even above the level of the aortic arch. The entire thoracic esophagus may now be resected in one stage with immediate restoration of continuity of the alimentary tract, and with an acceptable operative mortality. This permits the application of esophageal resection for palliation as well as in the curative treatment of carcinoma of the esophagus.

Fig. 446—Roentgenogram showing the most common location of carcinoma of the thoracic esophagus.

Unfortunately the esophagus is not as adaptable to cancer surgery as are structures with a serosal covering or those with a mesentery. The thoracic esophagus is even less satisfactory in this respect than is the cervical esophagus, for in the thoracic segment the tumor always has close anatomical relationship with important, even vital structures. The regional lymph nodes frequently are inaccessible, and widespread lymphatic metastases commonly occur.

Carcinoma of the esophagus may arise at any level from the hypopharynx to the cardia, but a large percentage of these tumors occur in the mid-thoracic region (Fig 446). Churchill and Sweet suggested division of the thoracic esophagus into four segments rather than the usual upper, middle, and lower thirds. This is rational, for resection with primary esophagogastric anastomosis is subject to cer-

tain modifications which are dependent upon the segment of the esophagus involved. The upper fourth of the esophagus, the supra-aortic portion, extends from the upper border of the arch of the aorta to the superior thoracic aperture. Resection of lesions in this location requires anastomosis of the cervical esophagus with the stomach or perhaps with a loop of intestine, the latter as a delayed procedure. The middle half of the esophagus extends from the superior border of the aortic arch to the inferior pulmonary vein, and tumors of this segment require high intrathoracic esophagogastric anastomosis, above or below the aortic arch, depending upon the location and extent of the growth. The lower fourth of the thoracic esophagus extends from the inferior pulmonary vein to the diaphragm. A low thoracic esophagogastrostomy is performed for tumors of this segment as well as for tumors of the abdominal esophagus and cardiac end of the stomach.

If the stomach is not long enough for the performance of cervical esophagogastrostomy following excision of tumors of the supra-aortic segment, it may be necessary to perform the Torek operation, leaving the patient with a cervical esophagostomy and a gastrostomy. Alimentary continuity may be restored later by suitable esophagoplasty. It may be necessary to sacrifice a part or all of the stomach where cancer of the lower esophagus shows extensive invasion of the gastric walls. Under such circumstances alimentary continuity is established by esophagojejunostomy.

TRANSPLEURAL RESECTION OF THE ESOPHAGUS

Torek performed the first successful resection of the thoracic esophagus for carcinoma in 1913, using a left transpleural approach. He incised the mediastinal pleura, exposed the tumor, and separated it from the surrounding structures, then divided the esophagus between ligatures below the cancer, and brought the upper end, with the tumor attached, out through a cervical incision. After resecting the tumor-bearing portion of the esophagus, he drew the distal end of the upper segment through an incision in the skin below the medial end of the clavicle and sutured it there. The operation, as modified by Eggers in 1931, constitutes the presently used technic for this type of resection

The patient is placed on his right side and both arms are elevated above the head; the left arm is left free so that the body may be rotated when necessary. The incision is started over the fourth rib and is extended down midway between the vertebral border of the scapula and the spine to the seventh intercostal space and is then carried forward along the entire length of that interspace The fourth, fifth, sixth, and seventh ribs are divided posteriorly, and the pleura is opened the full length of the incision. The collapsed lung is displaced forward to expose the pleura over the posterior mediastinum An incision is made through the mediastinal pleura from the diaphragm to the undersurface of the aortic arch, and the esophagus is exposed and freed a short distance from the tumor. Special care should be taken during this stage of the operation to clamp blood vessels before dividing them, in order to avoid obscuring the field by hemorrhage as well as to prevent loss of blood

A tape is placed around the free portion of the esophagus for use as a retractor, and an attempt is made to separate the tumor from the surrounding structures. This part of the operation is especially difficult when the growth lies posterior to the arch of the aorta. After the tumor has been completely isolated, an incision is

made through the pleura above the arch of the aorta and that portion of the esophagus is freed by finger dissection. If this manipulation produces shock, as it not infrequently does, the operation is discontinued temporarily, the rib spreader is removed, the lung is expanded, and oxygen is administered. After the patient has recovered sufficiently, the esophagus is divided by the cautery between ligatures placed at a safe distance below the tumor. The lower esophageal stump is inverted into the stomach by purse-string sutures. That portion of the esophagus containing the tumor is drawn up behind the aortic arch and out above it. The thorax is temporarily closed by skin clips and the patient is turned on his back for the cervical portion of the operation.

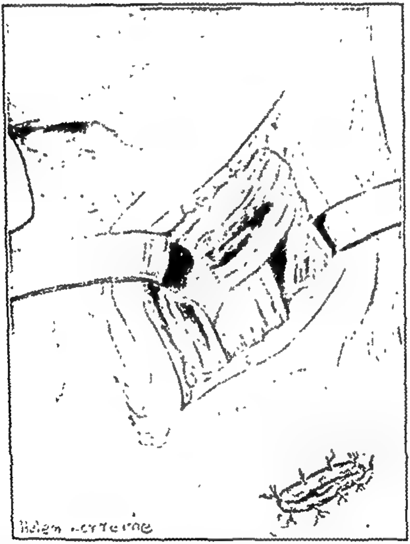


Fig. 447.—Torek's method of implanting the distal end of the proximal segment of the esophagus beneath the skin.

An incision about 8 cm. in length is made along the anterior border of the left sternocleidomastoid muscle, the lower cervical esophagus is isolated, and the entire upper segment is drawn out of the thorax and wrapped in warm moist gauze. The patient is again turned on his side, the wound is reopened, and the mediastinal pleura is closed. A soft rubber tube is inserted through a stab wound in one of the lower interspaces and the thoracic wound is closed. Before the final sutures are tied, the lung is fully expanded. Expansion of the lung is maintained by placing the distal end of the drainage tube under water.

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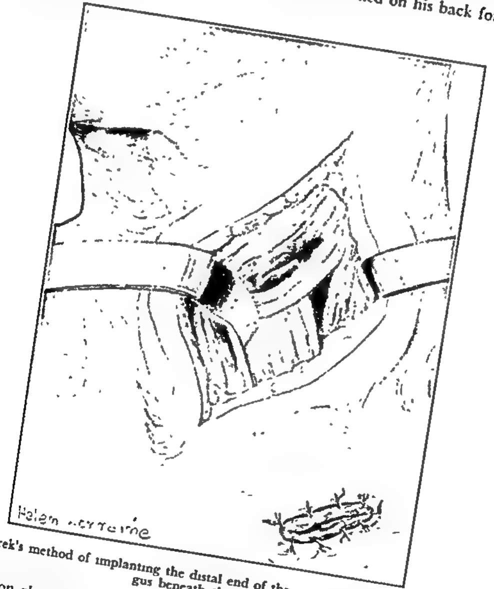

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The patient is again turned on his back and the muscles in the neck are sutured snugly but not too tightly around the esophagus. The esophagus is ligated well above the tumor and divided by the cautery distal to this ligature. A subcutaneous tunnel is made from the lower end of the cervical incision to a point below the inner end of the clavicle over the first or second intercostal space where a small transverse incision is made and the esophagus is drawn out through the incision and sutured to the margins of the skin (Fig. 447).

A gastrostomy is established preliminary to the Torek operation. When resection of the esophagus with immediate esophagogastrostomy is planned but, for any reason, proves to be inadvisable, Torek's operation should be done if feasible. It will then be necessary to do a gastrostomy following closure of the thoracic and cervical wounds. However, such a combination of circumstances rarely will be encountered. If the prognosis appears good, esophagoplasty may be done later.

PARTIAL ESOPHAGECTOMY WITH PRIMARY INTRATHORACIC ESOPHAGOGASTROSTOMY

This operation is applicable to tumors of the cardiac end of the stomach and the lower three-fourths of the esophagus.

On the morning of operation a Levine tube is passed transnasally into the esophagus and down to the point of obstruction. A cannula is inserted into the saphenous vein at the ankle, and blood is administered throughout the operation The patient is placed on his right side with the back at right angles to the operating table and with the left arm hanging free so to rotate the scapula forward. The skin incision is carried downward midway between the vertebral border of the scapula and the spinous processes of the vertebral column to the eighth rib, then forward along that rib to the costochondral junction (Fig. 448). The extent of the vertical portion of the incision will depend upon the location of the tumor. If the tumor lies in the middle half of the esophagus, it may be necessary to start the incision at the level of the fourth rib. If the tumor lies in the lower fourth of the esophagus, the vertical portion of the incision may be started at the level of the sixth rib. The muscle layers are divided in the line of the skin incision and the eighth rib is resected subperiosteally throughout its entire length. The pleural cavity is opened and the rib-spreading retractor is placed in the angle of the wound. The lung is retracted upward and forward and the mediastinal pleura is incised in line with the esophagus. If the tumor lies in the superior portion of the middle half of the esophagus, it is necessary to carry the incision in the mediastinal pleura above the aortic arch and posterolateral to the left subclavian artery. The esophagus is mobilized both above and below the tumor, care being taken to protect its blood supply until it has been determined whether or not the lesion is operable. Care must be exercised in freeing the tumor from the aorta and left stem bronchus, for direct extension of the carcinoma to these structures is common. If examination shows an operable lesion in the middle half of the esophagus, it is usually necessary to divide the seventh, sixth, and fifth ribs proximal to their angles to gain adequate exposure. The ribs are cut in an oblique plane so they can be fixed by on-end and circumferential wire sutures at the time of closure (Fig. 346). The phrenic nerve is crushed and the diaphragm is opened by a radial incision which extends from the lateral chest wall to the eso-

phageal hiatus. The liver and the regional lymph nodes in the left upper quadrant are carefully examined for metastases. This is important from the standpoint of prognosis, but inability to resect all of the involved lymph nodes does not necessarily contraindicate palliative resection.

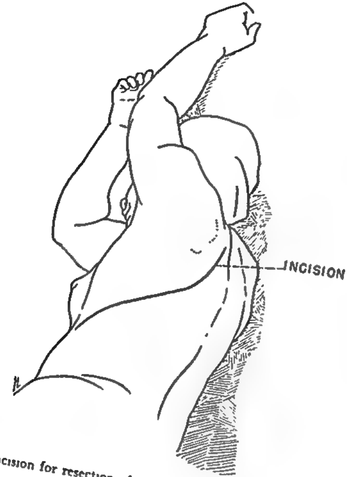

Fig 448 —Incision for resection of the mid portion of the thoracic esophagus.

The extent of mobilization of the stomach depends upon the length of esophagus it is necessary to resect. The stomach must be sufficiently mobilized to avoid tension on the suture line. The vasa brevia and the left gastroepiploic arteries are divided and ligated with fine silk (Fig. 449). The gastrocolic ligament is then incised, but great care must be taken to avoid injury to the anastomotic arcade of vessels along the greater curvature of the stomach Division of the gastrocolic ligament is carried to the pylorus if the stomach is to be brought up above the arch of the aorta. The right and left inferior phrenic vessels are ligated and the gastrophrenic ligament is divided, freeing the stomach from the diaphragm. Division of the left gastric vessels greatly increases the mobility of the stomach. The left gastric artery is divided close to its origin from the celiac axis. Exposure of this vessel is facilitated by dividing the tissues above and below it so that when the stomach is put on stretch, the vessels can be clearly identified. The gastrohepatic ligament is divided, but care must be exercised to preserve the right gastric and hepatic arteries (Fig 450). This extensive mobilization of the stomach usually is sufficient for intrathoracic esophagogastrostomy at any level. Less extensive mobilization is needed when only the lower fourth of the esophagus is resected The stomach may be fur-

ther mobilized for cervical esophagogastrostomy by dividing the peritoneum lateral to the duodenum. This permits the duodenum to be rolled mesially and its first portion can be brought up to the diaphragm.

For high intrathoracic esophagogastrostomy the esophagus is divided at the cardia, between Payr's clamps, and the distal end is inverted into the stomach by a running right angle suture of 00 chromic catgut. A row of interrupted fine silk sutures for the seromuscular layer completes the closure (Fig. 451). Carcinoma involving the lower esophagus and cardiac end of the stomach requires partial or rarely complete removal of the stomach (Fig. 452). For partial gastrectomy the stomach is divided at the indicated level between Payr's clamps. The distal segment of

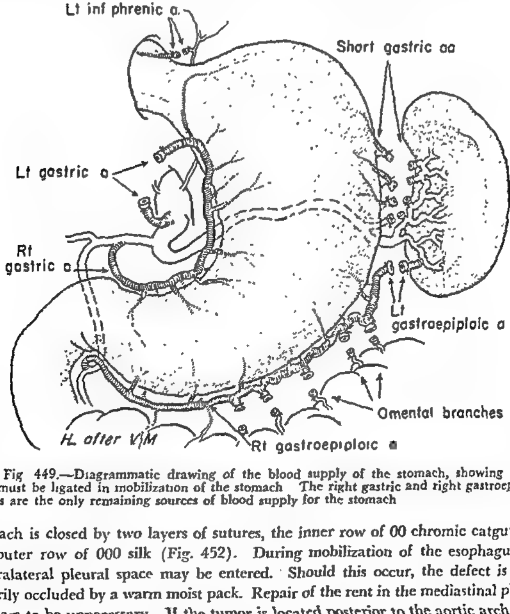

Fig 449.—Diagrammatic drawing of the blood supply of the stomach, showing vessels that must be ligated in mobilization of the stomach The right gastric and right gastroepiploic vessels are the only remaining sources of blood supply for the stomach

stomach is closed by two layers of sutures, the inner row of 00 chromic catgut and the outer row of 000 silk (Fig. 452). During mobilization of the esophagus the contralateral pleural space may be entered. Should this occur, the defect is temporarily occluded by a warm moist pack. Repair of the rent in the mediastinal pleura appears to be unnecessary. If the tumor is located posterior to the aortic arch, it is best to first mobilize the esophagus above and below the arch. Division of one or more of the highest intercostal arteries permits the arch to be displaced forward and this facilitates mobilization of the tumor In mobilizing the esophagus just above the aortic arch it must be remembered that the thoracic duct crosses the left side of the esophagus from a posterior to an anterior position just above the level of the

aortic arch. If the duct is torn during the dissection, it must be repaired or ligated to prevent the development of chylothorax. In freeing the esophagus the paraesophageal and other regional nodes should be removed with the esophagus (Fig. 453).

It is necessary to mobilize the esophagus and transplant it above the aortic arch when neoplasms arise in the upper portion of the middle half of the esophagus (Fig. 453). Anastomosis below the aortic arch usually is feasible in tumors of the inferior part of the middle half of the esophagus (Figs. 450 and 451).

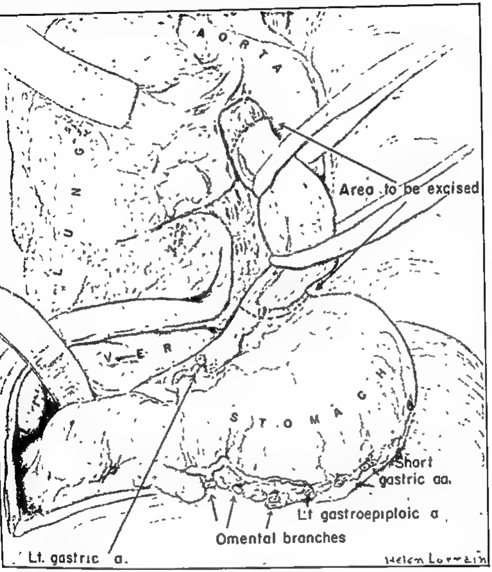

Fig 450—Extent of mobilization of the stomach and esophagus necessary for resection of carcinoma of the lower portion of the middle half of the esophagus.

During the process of mobilizing the stomach and transferring it into the thorax, it should be handled with care to avoid injury to the vessels of the stomach wall.

The open method of anastomosis is preferred between the stomach and esophagus. Two rows of interrupted fine silk sutures are used (Fig. 454), the inner row approximating the mucosa, the outer row the muscular coats. The fundus of the stomach occupies a considerably higher level than does the cardia, so the anterior wall of the fundus is always used in high anastomoses. The esophagus must be divided and the anastomosis done at least 5 cm above the upper border of the tumor. An oval or circular defect 3 cm. in diameter is made through the serosa and mus-

cularis of the stomach and the superficial vessels are ligated. Interrupted mattress sutures of four 0 silk are placed through the muscular portion of the posterior wall of the esophagus and through the seromuscular layer of the stomach, approximately 1 cm. of the wall of each structure being included (Fig. 454, *A*). All of the sutures are placed before any of them are tied, to avoid unnecessary trauma to the friable, easily torn esophageal wall. The esophagus is then amputated and the opening in

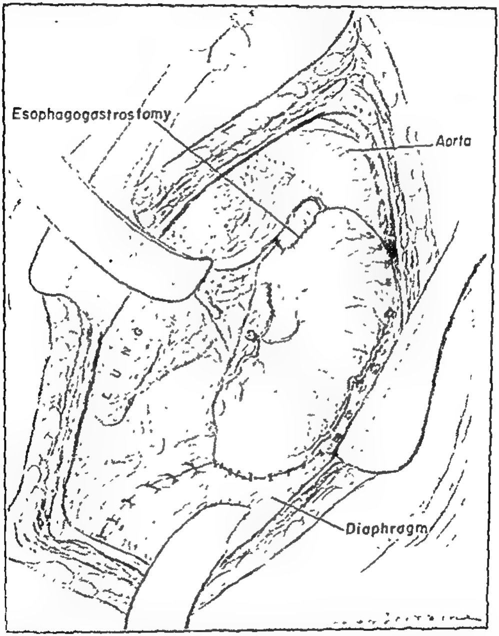

Fig 451 —Subaortic esophagogastrostomy following resection of carcinoma of the lower portion of the middle half of the esophagus.

the stomach is completed by excising a circular area of mucosa. The Levine tube is withdrawn to a point just above the level of anastomosis and is connected with continuous suction. Another aspirating tube is used to empty the stomach, thereby preventing gross contamination of the operative field. A second row of interrupted silk sutures is placed through the entire thickness of the walls of the stomach and esophagus and tied on the inside These sutures are placed so that they accurately

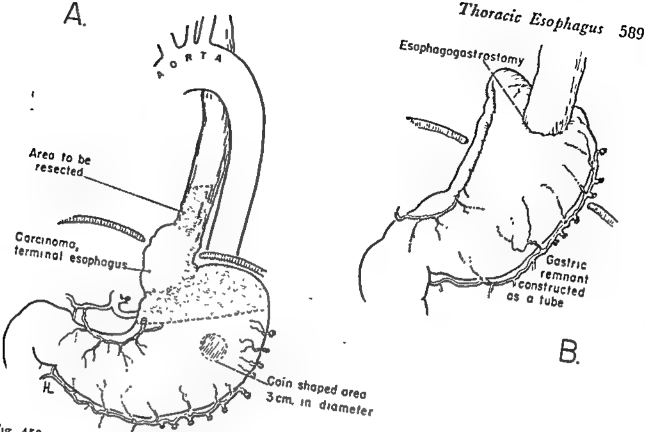

Fig 452.—*A*, Carcinoma of terminal esophagus requiring partial resection of the stomach preliminary to esophagogastrostomy. *B*, Anastomosis completed.

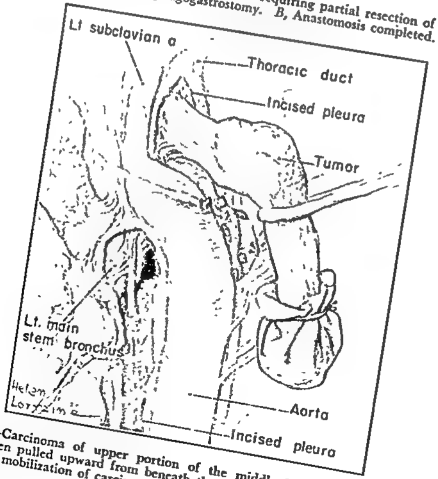

Fig 453.—Carcinoma of upper portion of the middle half of the esophagus. The esophagus has been pulled upward from beneath the aortic arch. Division of two intercostal arteries facilitates mobilization of carcinoma in this location.

approximate the two mucosal layers (Fig. 454, *B*). The first anterior row of sutures is placed and tied in a similar manner (Fig 454, *C*). The closure is completed by an outer anterior line of interrupted silk sutures (Fig. 454, *D*). A segment of gastrocolic omentum is anchored about the anastomosis with interrupted silk sutures The stomach is fixed to the mediastinal pleura by interrupted silk sutures. Antibiotics may be placed in the abdominal cavity and the margins of the peripheral portion of the incision in the diaphragm are approximated by interrupted silk sutures while the margins of the medial portion are sutured to the gastric wall (Fig. 455).

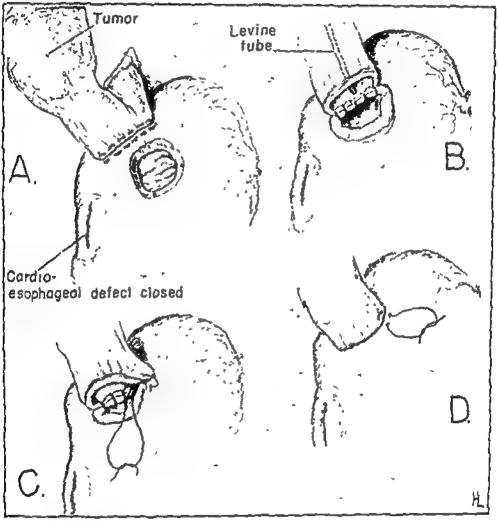

Fig 454.—Open anastomosis between the stomach and esophagus.

The pleura is thoroughly flushed with physiologic salt solution. A mushroom catheter is inserted through the third intercostal space anteriorly and a No. 32F catheter is inserted through the ninth intercostal space in the posterior scapular line. The ribs which were severed posteriorly are wired together by on-end and circumferential wire sutures (Fig 346).

The patient is placed in the Trendelenburg position and nasal oxygen is started. The Levine tube is removed. When the patient has reacted and his blood pressure has become stabilized, he is placed in Fowler's position. If the right pleural cavity was entered during the operation, an x-ray of the chest is made following closure of the wound to determine whether or not all air has been aspirated from that side.

Care is exercised to prevent the accumulation of secretions in the tracheobronchial tree. Intratracheal catheter suction usually suffices, but, if this is not effective, bronchoscopy is in order. The intercostal tubes are removed on the second postoperative day. Small quantities of water are permitted by mouth after forty-eight hours, and thereafter an increasing diet of frequent small feedings is allowed. Within a week or ten days many patients are able to take a soft diet.

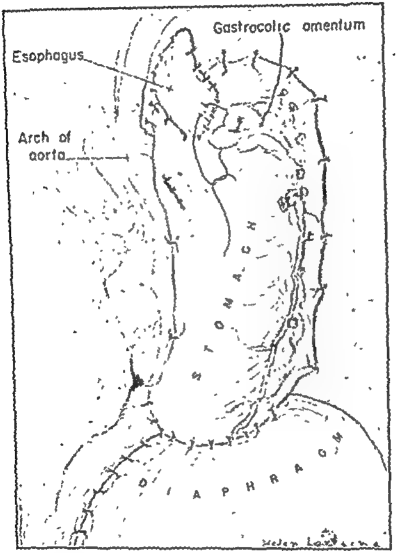

Fig. 455. [illegible]
by a cuff [illegible]
suturing [illegible]
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RESECTION OF THE ESOPHAGUS FOR SUPRA-AORTIC CARCINOMA WITH PRIMARY CERVICAL ESOPHAGOGASTROSTOMY

This operation is applicable to tumors of the supra-aortic thoracic esophagus and tumors situated low in the cervical esophagus.

Operability may be estabilshed by exploring the supra-aortic esophagus through a cervical incision. The neck, shoulder, forearm, and left chest are prepared for operation. The forearm is inclosed by sterile drapes. The patient is placed on his back with the head extended and turned to the right. A *skin incision* is made along the anterior border of the left sternocleidomastoid muscle extending from the level

the hyoid bone to the sternal notch. The sternocleidomastoid muscle and the otid sheath vessels and vagus nerve are retracted laterally, and the left lobe of thyroid gland is drawn medially. Division of the inferior thyroid artery per-s a more adequate exposure of the cervical esophagus. The supra-aortic region explored by finger palpation. Tumors of the superior fourth of the thoracic phagus usually can be palpated and outlined by this method. If the tumor can separated from the trachea on the mesial side and from the aortic arch anteriorly, s considered resectable. The wound is temporarily closed with skin clips and the ient is turned on his right side. The left arm is permitted to hang free over the ;e of the table so as to displace the scapula laterally.

An incision is made along the eighth rib from the costochondral junction to dway between the vertebral border of the scapula and the spinous processes, ere it is directed upward to the level of the fourth rib. The eighth rib is resected periosteally and the seventh, sixth, and fifth ribs are divided posterior to their gles. The pleural cavity is opened and the dissection is begun in the region of tumor. The mediastinal pleura is incised posterolateral to the left subclavian ery and the region of the tumor is carefully examined to make certain that re-tion is feasible. It must be remembered that the thoracic duct crosses the esopha-s on the left or laterally just above the aortic arch. After the tumor and supra-tic part of the esophagus have been completely mobilized, the distal esophagus mobilized. The phrenic nerve is crushed and the diaphragm is incised from the phageal hiatus to the lateral chest wall. After mobilization of the stomach has en completed, as described in the first part of this chapter, the esophagus is ided just above the cardia and the distal stump is inverted into the stomach h a running right angle suture of 00 chromic catgut. A second row of inter-pted fine silk sutures completes the closure. The proximal stump is covered by ize, which in turn is covered by rubber dam; the esophagus is then delivered ove the aortic arch.

The fundus of the stomach is drawn up posterior to the hilum of the lung and her lateral or posterior to the aortic arch to the dome of the left thoracic cavity. e stomach is fixed in this position by interrupted silk sutures which are placed ough the midgastric wall and the mediastinal pleura over the descending aorta. e fundus of the stomach lies free in the superior portion of the pleural cavity and y actually appear to be redundant. The diaphragm is closed peripherally with errupted silk sutures, while medially the free edges of the diaphragm are fixed to gastric wall, just above the pylorus, by interrupted silk sutures.

The cervical incision is reopened and the thoracic esophagus is delivered from chest. Sponge forceps are introduced through the cervical incision and the fun-s of the stomach is gently manipulated up into the cervical wound. The stomach usually not unduly compressed by the superior thoracic aperture. The mediastinal ura is closed by interrupted sutures of fine silk and the pleura is washed thor-ghly with saline solution. A mushroom catheter is inserted through the third in-costal space anteriorly and a No 32F catheter is placed in the ninth intercostal ace in the posterior scapular line. The wound is closed in layers.

The patient is turned on his back and the edges of the cervical wound are re-cted, exposing the fundus of the stomach and the esophagus. The esophagus is iputated well above the tumor and an anastomosis is made between the stump of

the esophagus and the fundus of the stomach, end to side. Careful approximation of mucosa to mucosa is essential. The fundus of the stomach is fixed to the prevertebral fascia by interrupted sutures of fine silk so as to prevent tension on the anastomosis. The cervical fascia and skin are closed by interrupted sutures. The wound is not drained.

Sweet believes that the space through which the esophagus normally passes from the neck to the superior mediastinum is not large enough to accommodate the fundus of the stomach. He also feels there is not sufficient room for a satisfactory anastomosis between the spine, the trachea, and the carotid sheath. To correct this, he devised an operation in which he resected the inner half of the clavicle and a corresponding segment of the first rib. This allowed the fundus of the stomach to be passed into the neck to meet the esophageal segment without pressure or constriction. We have been able to perform cervical esophagogastrostomy without too great difficulty, by rotating the larynx so as to bring the esophageal stump into ready approximation with the fundus of the stomach. No symptoms suggestive of constriction of the stomach at the superior thoracic aperture have been noted.

COMBINED ABDOMINOTHORACIC APPROACH FOR CARCINOMA OF THE ESOPHAGUS

Patients with tumors involving the abdominal portion of the esophagus or the cardiac end of the stomach may well be subjected to an exploratory laparotomy, as suggested by Garlock, to determine whether or not the lesion is operable. If intra-abdominal exploration reveals fixation of the growth to vital structures, extensive seeding of the peritoneum with tumor implants, massive hepatic metastases or extensive retroperitoneal lymph node invasion, resection of the esophagus is abandoned and a gastrostomy is performed.

The patient is placed on his right side with the dependent thigh flexed to support the pelvis. The body is so placed that the back forms an angle of about 60 degrees with the surface of the table. The left arm is supported on pillows so as to permit this rotation of the trunk. The eighth rib is identified and its junction with the cartilaginous arch is marked by a scratch. A transverse upper abdominal incision is made opposite this mark and the left rectus muscle is transected. If the tumor appears to be operable, the incision is extended on to the thorax along the course of the eighth rib (Fig 456), which is resected subperiosteally and the costal arch is divided. Resection of the esophagus with reestablishment of alimentary continuity is carried out as previously described

Some surgeons prefer the combined abdominal and right thoracic approach, originally described by Ivor Lewis in 1946, for resection of esophageal neoplasms. The thoracic esophagus is more easily resected through the right pleural cavity since the azygos vein is the only important structure requiring division. The aortic arch is thereby avoided, and this greatly facilitates mobilization of the esophagus. Also, the anastomosis is easier to perform from the right side, when the tumor lies in the upper portion of the middle half of the esophagus. The procedure can be carried out in one or two stages The first stage consists of making an upper transverse or left paramedian abdominal incision, exploration of the abdomen, and mobilization of the stomach Division of the left coronary ligament and retraction of the left lobe of the liver to the right gives a satisfactory exposure of the terminal esopha-

of the hyoid bone to the sternal notch. The sternocleidomastoid muscle and the carotid sheath vessels and vagus nerve are retracted laterally, and the left lobe of the thyroid gland is drawn medially. Division of the inferior thyroid artery permits a more adequate exposure of the cervical esophagus. The supra-aortic region is explored by finger palpation. Tumors of the superior fourth of the thoracic esophagus usually can be palpated and outlined by this method. If the tumor can be separated from the trachea on the mesial side and from the aortic arch anteriorly, it is considered resectable. The wound is temporarily closed with skin clips and the patient is turned on his right side. The left arm is permitted to hang free over the edge of the table so as to displace the scapula laterally.

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gus. The esophagus is freed above the diaphragm for a distance of approximately 5 cm. and the right crus of the diaphragm is divided near its origin, as suggested by Macmanus. This gives a larger space through which to transfer the stomach into the chest. This is done during the thoracic stage of the operation. Closure of the abdomen completes the first stage of the operation. The second stage may be carried out immediately, or after one week. In any event, the seventh rib is resected subperiosteally, the terminal esophagus is mobilized, and the stomach is drawn into the right thoracic cavity. Fixation of the stomach and esophagogastrostomy are completed by methods previously described.

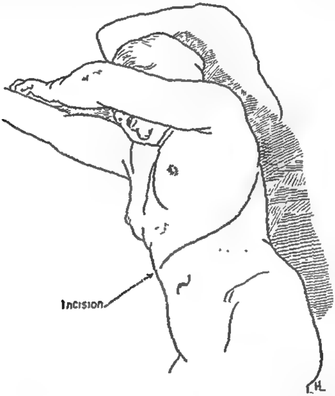

Fig. 456.—Upper abdominal transverse incision is made for the purpose of exploration The incision is extended on to the thorax along the course of the eighth rib for operable tumors of the esophagus.

BENIGN TUMORS OF THE ESOPHAGUS

A benign neoplasm of the esophagus may prove to be adenoma, fibroma, hemangioma, lipoma, myxofibroma, neurofibroma, papilloma, polyp, enterogenous cyst, or leiomyoma Tumors arising from the mucosa or submucosa, commonly known as mucosal tumors, are often pedunculated and covered by normal epithelium. Tumors arising from the outer coat of the esophagus are described as intramural or extramucosal. Benign tumors of the esophagus are rare, but, when present, a large percentage of them eventually require surgery because of obstructive symptoms, infection, or hemorrhage It is frequently possible to excise the mucosal type of tumor through the esophagoscope, but the extramucosal growths require thoracotomy. Those requiring transpleural excision usually prove to be enterogenous cysts or leiomyomas. Enterogenous cysts are well encapsulated and usually require only simple excision with closure of the muscular coat of the esophagus by interrupted sutures of fine silk Leiomyomas may be solitary and encapsulated; multiple, with ex-

tensive involvement of a large segment of the esophagus; and diffuse, with involvement of the entire circumference of the outer wall of the esophagus.

Solitary encapsulated leiomyomas are usually found in the distal third of the esophagus and are amenable to simple transpleural enucleation with closure of the defect in the muscular wall of the esophagus by interrupted sutures of fine silk. Diffuse leiomyomas and tumors of multicentric origin involving a large segment of the esophagus require partial esophagectomy and esophagogastrostomy. The gastric cardia also may show involvement. In one patient with extensive involvement of the muscular coats of the esophagus and cardia by a tumor of multicentric origin, we were forced to do a total thoracic esophagectomy and partial gastrectomy. A tube, constructed from the greater curvature of the stomach, was anastomosed to the cervical esophagus

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CHAPTER 39

CONGENITAL ATRESIA OF THE ESOPHAGUS

PRIMARY ANASTOMOSIS; DELAYED ANASTOMOSIS

I. A. Bigger

Remarkable progress has been made in the treatment of congenital atresia of the esophagus in the decade which has elapsed since Cameron Haight performed the first successful end-to-end anastomosis of the esophageal segments. Atresia of the esophagus sometimes occurs as an isolated anomaly, but usually there is an associated tracheoesophageal fistula. The presence of an associated tracheal fistula is of practical importance in connection with the treatment of esophageal atresia since, in a large percentage of cases in which there is a fistula, end-to-end anastomosis of the esophageal segments is possible. Only in a very small percentage of cases with fistula does one find both proximal and distal esophageal segments so short that direct anastomosis is impossible. On the other hand, in cases of atresia of the esophagus without associated tracheal fistula, the distal esophagus usually is aplastic or even absent, and direct anastomosis is rarely possible. Fortunately, direct anastomosis of the esophageal segments is feasible in approximately 80 per cent of all cases of congenital esophageal atresia.

Since the management of these cases, including the surgical approach, hinges on the feasibility of direct anastomosis, it is important that the presence or absence of associated tracheal fistula be determined, and, even when it is obvious that there is a fistula, an attempt should be made to determine the length of both esophageal segments. This may be accomplished by endoscopy or by the injection of small amounts of iodized oil into the trachea and esophagus, making the tracheal injection first. If the position of the fistula in relation to the tracheal bifurcation can be demonstrated, one gains a reasonably accurate idea of the length of the distal esophageal segment. Oil is then placed in the proximal esophageal segment and the length of that segment is determined by fluoroscopy and by roentgenograms.

If it appears that primary anastomosis is feasible, the right posterior extrapleural approach should be employed. As a preliminary to thoracotomy, the infant should be well hydrated, and in the majority of cases a blood transfusion is advisable. The child should be given antibiotics, especially penicillin, to aid in preventing aspiration pneumonia. When there is distention of the stomach and intestines with air, a simple multiple purse string, or a Witzel type of gastrostomy should be done twenty-four hours before thoracotomy. The gastrostomy is easily and satisfactorily established under local anesthesia. The gastrostomy tube is used preoperatively for the evacuation of air and gastric juice. The distention rapidly subsides and drainage of the gastric juice prevents regurgitation and aspiration of

this irritating fluid into the bronchial tree. The relief of distention makes the anesthesia problem less difficult and thereby improves the prognosis. If the esophageal segments are so widely separated that primary anastomosis probably cannot be done, preliminary gastrostomy may be inadvisable since it may be necessary to transplant the greater part of the stomach into the thorax for anastomosis with the proximal esophageal segment. The anesthetic for the right extrapleural approach should be administered through a snugly fitting mask rather than by intratracheal tube, thereby avoiding the danger of edema of the glottis. The infant is placed in the prone position with the right side slightly elevated on a folded towel and the right arm is carried above the head to elevate the scapula. The incision

Fig. 457.—Photograph showing incision for right extrapleural approach to congenital esophageal atresia with tracheoesophageal fistula.

(Fig. 457) is started about 2 cm. from the spine at the level of the fourth intercostal space and is carried laterally and slightly caudally below the angle of the scapula to the midaxilla. The fourth rib is resected subperiosteally throughout the length of the superficial incision. The head of the rib may be disarticulated so as to avoid laceration of the pleura against the rib end. The internal periosteum is carefully incised to within 1 cm. of the anterolateral cut end of the rib. The periosteum is left intact near the cut end of the rib to avoid pleural injury. The edges of the periosteum are very carefully pushed back on each side of the incision with the knife handle and are then picked up with small curved hemostats, and the pleurolysis is continued above, below, and medially. After the pleura has been

CHAPTER 39

CONGENITAL ATRESIA OF THE ESOPHAGUS

PRIMARY ANASTOMOSIS; DELAYED ANASTOMOSIS

I. A. Bigger

Remarkable progress has been made in the treatment of congenital atresia of the esophagus in the decade which has elapsed since Cameron Haight performed the first successful end-to-end anastomosis of the esophageal segments. Atresia of the esophagus sometimes occurs as an isolated anomaly, but usually there is an associated tracheoesophageal fistula. The presence of an associated tracheal fistula is of practical importance in connection with the treatment of esophageal atresia since, in a large percentage of cases in which there is a fistula, end-to-end anastomosis of the esophageal segments is possible. Only in a very small percentage of cases with fistula does one find both proximal and distal esophageal segments so short that direct anastomosis is impossible. On the other hand, in cases of atresia of the esophagus without associated tracheal fistula, the distal esophagus usually is aplastic or even absent, and direct anastomosis is rarely possible. Fortunately, direct anastomosis of the esophageal segments is feasible in approximately 80 per cent of all cases of congenital esophageal atresia.

Since the management of these cases, including the surgical approach, hinges on the feasibility of direct anastomosis, it is important that the presence or absence of associated tracheal fistula be determined, and, even when it is obvious that there is a fistula, an attempt should be made to determine the length of both esophageal segments. This may be accomplished by endoscopy or by the injection of small amounts of iodized oil into the trachea and esophagus, making the tracheal injection first. If the position of the fistula in relation to the tracheal bifurcation can be demonstrated, one gains a reasonably accurate idea of the length of the distal esophageal segment. Oil is then placed in the proximal esophageal segment and the length of that segment is determined by fluoroscopy and by roentgenograms.

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this irritating fluid into the bronchial tree. The relief of distention makes the anesthesia problem less difficult and thereby improves the prognosis. If the esophageal segments are so widely separated that primary anastomosis probably cannot be done, preliminary gastrostomy may be inadvisable since it may be necessary to transplant the greater part of the stomach into the thorax for anastomosis with the proximal esophageal segment. The anesthetic for the right extrapleural approach should be administered through a snugly fitting mask rather than by intratracheal tube, thereby avoiding the danger of edema of the glottis. The infant is placed in the prone position with the right side slightly elevated on a folded towel and the right arm is carried above the head to elevate the scapula. The incision

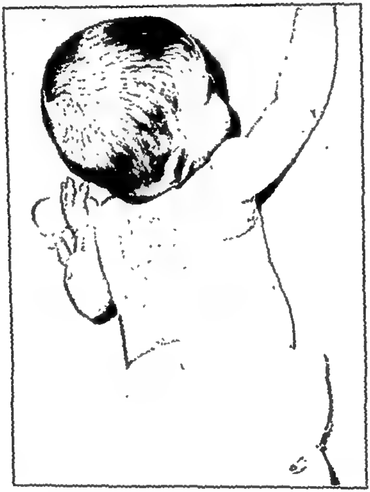

Fig. 457.—Photograph showing incision for right extrapleural approach to congenital esophageal atresia with tracheoesophageal fistula

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freed for a short distance on each side of the incision, the pleurolysis can be co tinued by careful finger dissection, with the tips of the fingers pressed against t ribs and intercostal muscles rather than against the pleura. (Fig. 458.) T azygos vein is dissected out, doubly clamped, divided, and ligated with four 0 si

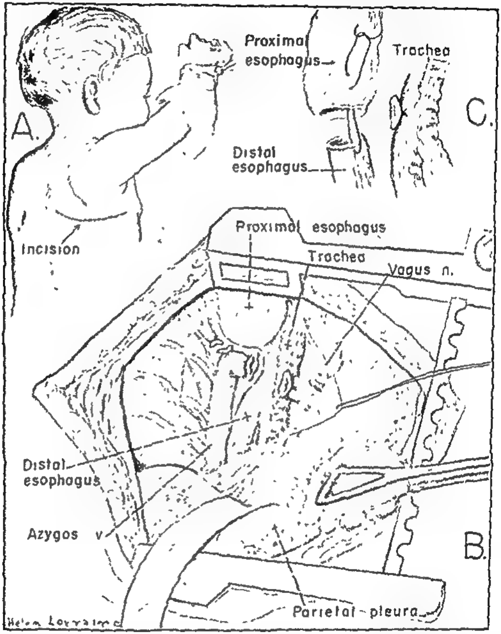

Fig 458.—*A*, Position of patient and line of incision *B*, Dilated proximal stump of the esophagus with the esophagotracheal fistula and the azygos vein divided. *C*, Fistula separated and anastomosis between proximal and distal ends of esophagus started.

The fistula is now exposed; the distal segment of esophagus is dissected out for about 2 cm. and is ligated with 000 silk as near as possible to the trachea. A small hemostat is placed across the esophagus approximately 0.5 cm. from the ligature, and the esophagus is divided against the clamp by a sharp knife. The proximal cut end is treated with phenol and alcohol, and attention is directed to the upper esophageal pouch. This is usually readily located, but, should this prove difficult, the anesthetist can insert a small catheter which will make identification easy. Two fine traction sutures are inserted near the fundus, and the tip is incised

transversely for 1 to 1.5 cm. The anastomosis may then be completed by telescoping the small distal segment (Fig. 458, *C*) into the proximal segment or by a simple, open, end-to-end anastomosis with closely spaced interrupted sutures of four 0 silk. One row of properly placed sutures probably is sufficient, but a few more widely spaced supporting sutures usually seem desirable. When two rows of sutures are used, however, it is important that the first row be tied so the knots will present within the lumen, not between the suture lines.

A small rubber catheter is inserted through an interspace near the lower level of pleurolysis and close to the spine. The tip of the catheter is fixed by one four 0 plain catgut suture near, but not in contact with, the suture line or the site of the obliterated fistula. Slight suction may be applied through this catheter, but water-seal drainage usually suffices and may be safer. The catheter is used as an avenue of escape for air and fluid in case of leakage from the esophagus or trachea. Even more important, it prevents the accumulation of fluid in the region of the suture line, thus permitting the adjacent tissues to come in contact with and adhere to the area of anastomosis. The chest wall incision is closed in layers with four 0 plain catgut for the skin. A gauze dressing is applied but is removed the following day and the incision is painted over with collodion.

Postoperatively both penicillin and streptomycin are given for several days. The gastrostomy tube is attached to the barrel of an Asepto syringe which is supported well above the body level so as to permit the escape of air but prevent loss of gastric juice or food. It is, of course, used temporarily for feeding.

When it is evident that the esophageal segments cannot be brought together without mobilization of the stomach, a transpleural approach should be used. If the distal esophageal segment appears to be satisfactory except for a low junction with the trachea (carina) or a main bronchus, approach probably is best made through the right side, for anastomosis of the esophageal segments is simpler and more satisfactory from that side. Entrance to the right pleural cavity should be through the bed of the eighth rib or the eighth intercostal space. The mediastinal pleura is incised, and the lower esophagus is freed from the adjacent structures. The hiatus is enlarged and the cardia is freed up and elevated above the diaphragm. It may be necessary to ligate and divide the left gastric artery near its origin before the cardia can be appreciably elevated. A sufficient number of ribs may then be divided posteriorly to give adequate exposure for closure of the fistula and anastomosis of the esophageal segments or for esophagogastrostomy. Should esophageal anastomosis prove to be impossible, the stomach may be brought up for primary esophagogastrostomy, as described by Madden. However, primary anastomosis of the esophageal segments should be done if it is at all possible, for the results are more satisfactory than are those obtainable by other means. When there is no fistula, the distal segment of esophagus usually is aplastic. Under such circumstances one has to decide whether to do a primary esophagogastrostomy or cervical esophagostomy and gastrostomy with the idea of doing an esophagogastrostomy at a later date, as recommended by Sweet. This is a difficult decision, but, if the child's condition is satisfactory, primary esophagogastrostomy seems preferable even though the mortality from this procedure has so far been discouragingly high. If primary intrathoracic esophagogastrostomy is decided upon, the left transpleural approach should be used. When there is no fistula and the child's condition contraindicates extensive surgery, one may do a *simple gastrostomy* for feeding, and

wait, taking especial pains to see that the upper esophageal pouch is kept emptied by suction. At a later date, when the child's condition is sufficiently improved, one has the choice of doing an intrathoracic esophagogastrostomy or esophagojejunostomy, utilizing the Roux principle or the technic described by Harrison.

Sweet suggests that when primary esophageal anastomosis is not feasible, a cervical esophagostomy be established, and, if there is tracheal fistula, that should be closed. A day or two later a gastrostomy is performed. Sweet believes it may be wise to wait two years or more before reestablishing the continuity of the gastrointestinal tract. For this final operation, he enters the left chest through the eighth intercostal space, then makes a long radial incision through the diaphragm. The aplastic distal esophagus is excised and the stump is inverted into the stomach. The stomach is separated from the anterior abdominal wall and the gastrostomy opening is closed. The left gastric and left gastroepiploic arteries and vasa brevia are ligated and divided. The gastrocolic and gastrohepatic omenta are divided between ligatures to near the pylorus, care being exercised to avoid injury to the right gastric and right gastroepiploic arteries and to the marginal loops, since these vessels are essential for the supply of blood to the wall of the stomach. The stomach is carried high into the left chest and fixed there. The diaphragm is paralyzed by crushing the phrenic nerve, and the opening in the diaphragm is closed around the antral portion of the stomach.

The thoracotomy incision is closed and an intercostal catheter is placed for water-seal drainage. The child is turned to the dorsal recumbent position and a vertical incision is made from the esophagostomy opening to the second rib; the sternocleidomastoid muscle is severed and retracted laterally. The sternal half of the clavicle and a segment of the first rib are resected along with the periosteum. The esophagostomy stoma is freed up; the fundus of the stomach is brought up and an end-to-side anastomosis is done. This anterior wound is closed without drains. This procedure is preferable to the use of antethoracic skin tubes but is obviously less satisfactory than end-to-end anastomosis of the esophageal segments and should be used only when the more ideal procedure is not feasible.

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CHAPTER 40

DIAPHRAGMATIC HERNIA

I. A. Bigger

Diaphragmatic hernias may be congenital or acquired. The acquired hernias may be divided into the traumatic and nontraumatic varieties. It is probable, however, that most of the nontraumatic, so-called acquired, hernias are due primarily to weakness of the diaphragm and so, in a sense, are congenital. Congenital hernias may occur at the esophageal hiatus, through a persistent pleuroperitoneal defect, called the foramen of Bochdalek, or anteriorly through the foramen of Morgagni. The great majority of nontraumatic acquired hernias pass through the esophageal hiatus. Hernias due to direct trauma may, of course, occur through any portion of the diaphragm, but those resulting from compressing injuries of the abdomen and thorax usually pass through the left leaf of the diaphragm, more often through its lateral portion or dome. Most traumatic hernias of the diaphragm are not covered by a sac and are, therefore, not true hernias. In fact, true hernias form only a small percentage of the total number occurring through openings other than the esophageal hiatus Harrington estimates that esophageal hiatus hernias occur from three to four times as frequently as all other diaphragmatic hernias combined.

The indications for operation differ in the various types of diaphragmatic hernia. Operation is indicated in the great majority of traumatic diaphragmatic hernias because of the danger of strangulation. The incidence of strangulation is greater in this group of hernias because they usually contain both small and large bowel and also because of adhesions between the various loops of bowel, one with another, as well as between loops of bowel and adjacent structures.

Congenital diaphragmatic hernias in infants, especially those resulting from persistence of the pleuroperitoneal opening (foramen of Bochdalek) should be operated upon promptly; in fact, they should be treated as semiemergencies when there is marked interference with respiration and circulation, as is so often the case. Otherwise, as pointed out by Ladd and Gross, a large percentage of these infants will die during the early weeks of life. Decision as to whether or not to operate upon congenital hernias through the esophageal hiatus should be made on the basis of the character and severity of symptoms.

Paresophageal hiatus hernias frequently produce disagreeable, even serious pressure on the heart and lungs, the result of the trapping of air in the intrathoracic portion of the stomach; also in large paresophageal hernias the colon may be drawn up through the hiatus and may become partially or completely obstructed. Rarely volvulus of the stomach occurs, urgently demanding operative intervention.

Sliding hiatus hernias contain only stomach and do not become strangulated or obstructed but often produce annoying symptoms such as belching and regurgitation of acid material. These symptoms are most pronounced when the patient bends over or lies down. Also sliding hernias sometimes are productive of attacks of pain, which may occur in the high epigastrium or substernal area and may radiate to the back or shoulders. Repeated regurgitation of the acid gastric contents may produce ulceration of the lower esophagus which in turn may lead to esophageal stricture.

Operation should therefore depend upon the severity of symptoms and the physical and roentgenologic findings. Persistent symptoms and even superficial excoriation or ulceration of the esophageal mucosa probably should be considered indications for operation if there are no significant contraindications to surgery.

Short esophagus hernia may give rise to essentially the same symptoms as are caused by sliding hernias, but the results of operation are distinctly less satisfactory in the short esophagus group.

Harrington recommends paralysis of one side of the diaphragm for palliation in certain hiatus hernias in patients who are poor risks for extensive surgery. Relief from the intermittent attacks of pain of incarceration secondary to spasm of the diaphragm may be obtained by this simple procedure, but the patients should be warned that they will continue to have the other unpleasant symptoms associated with this type of hernia.

The approach for repair of diaphragmatic hernias must be decided upon after taking a number of facts into consideration. These include the size, location and contents of the hernia, the physical characteristics of the patient, and of course the surgeon's experience and preference. Harrington uses the abdominal approach in practically all diaphragmatic hernias, other than lateral hernias on the right side. Other surgeons practically always use the thoracic approach. In the majority of cases the thoracic approach gives a more adequate exposure and allows a more satisfactory repair. There are, however, certain exceptions to this general rule. Congenital diaphragmatic hernias in infants, especially those through lateral pleuroperitoneal defects, are more satisfactorily approached through the abdomen. This is true largely because of the difficulty of replacing the contents of these hernias in the unopened abdomen. Retrosternal hernias (through the foramen of Morgagni) also are more readily repaired from below. Paresophageal hernias in individuals with a wide costal arch may be satisfactorily repaired from below. For the repair of paresophageal hiatus hernias, Harrington uses an oblique left rectus incision extending from the xiphoid process downward and outward to the lateral border of the rectus sheath. The coronary ligament of the liver is divided, and the left lobe of the liver is retracted to the right (Fig. 459). The herniated organs are reduced and, if a sac is present, as in esophageal hiatus hernias, it is best dissected out, but, if this adds too much to the operation, it may be pulled downward and divided around the circumference of the ring so that its cut edge will retract within the mediastinum. This leaves the margins of the ring uncovered by peritoneum and apparently gives quite satisfactory results. The enlarged esophageal hiatus is narrowed to the point where only sufficient room is left for the esophagus. The repair of the opening should be done by overlapping its margins, by two rows of interrupted medium silk sutures (Figs. 460 and 461). In hiatus hernias a large

Fig 459.—Diaphragmatic hernia. Exposure of hiatus hernia through the abdomen Note that the coronary ligament has been divided and the left lobe of the liver turned to the right.

Fig 460.

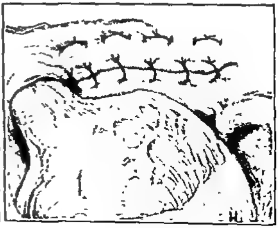


Fig. 461.

Fig. 460.—Diaphragmatic hernia. Repair of the dilated esophageal hiatus after removal of the hernial sac.

Fig. 461.—Diaphragmatic hernia. The repair has been completed.

mach tube should be passed before the closure is completed so as to avoid too
at narrowing of the esophageal lumen. Harrington usually does a preliminary
nporary paralysis of the left diaphragm.

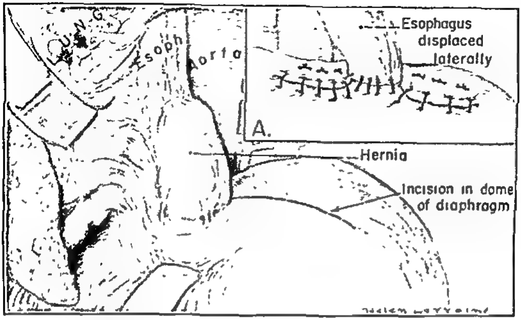
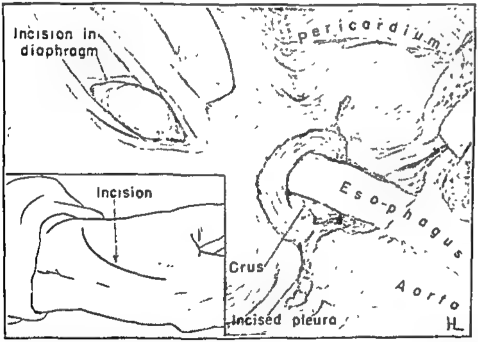


Fig. 462.—Modified Rives operation for the cure of paresophageal hiatus hernia. The ɔhagus is displaced laterally into the central tendon The esophagus is fixed to the periph- l end of the wound



ig 463 —Allison's operation for sliding hiatus hernia. The skin incision is shown in inset

Rives uses a posterolateral incision through the left eighth intercostal space or the bed of the resected ninth rib. Upon entering the thorax he proceeds imme- tely to incise the diaphragm from the center of the dome through the lateral rgin of the hiatus The index finger of the left hand is then inserted through s incision into the sac, which is dissected free and is completely excised. The

lower esophagus is then mobilized. If the esophagus is short, he sutures the stomach wall to the anterior, medial, and posterior margins of the hiatus. The greater curvature is sutured without constriction to the margins of the diaphragmatic incision. The remainder of the incision in the diaphragm is closed by imbrication with two rows of silk sutures. As indicated by this procedure, Rives believes symptoms are produced by the diaphragmatic constriction of the distended stomach. When the esophagus is of normal length, Rives transplants it laterally into the tendinous portion of the diaphragm and closes the medial portion of the opening by imbrication with silk sutures, thus placing the mobile fundus beneath the strongest section of the diaphragm. (Fig. 462.)

Sliding hernias are encountered more frequently than the paresophageal or short esophagus varieties. Allison believes the symptoms associated with sliding hernias are due to failure of the diaphragmatic pinchcock to function because of stretching and distortion of the posterior portion of the right crus by gastric pressure. This allows straightening of the esophagogastric junction and destroys the effectiveness of the so-called pinchcock action, allowing acid gastric juice to regurgitate into the esophagus. The operation developed by Allison for the relief of this condition was designed with the idea of maintaining the stomach within the abdomen and, more important, of restoring the effective action of the diaphragmatic pinchcock in preventing the regurgitation of gastric contents into the esophagus. The operation is in this respect the most rational procedure yet described for the cure of sliding hiatus hernias. The left thorax is entered through the bed of the ninth rib, the incision extending the full length of that rib. The mediastinal pleura is incised over the esophagus from the inferior margin of the left hilum to the diaphragm. The pleural incision is then extended forward onto the pericardium and backward across the aorta to the spine. (Fig. 463.) The esophagus is mobilized above the cardia, care being taken to protect the vagus nerves. A radial incision 7 to 8 cm. in length is made through the diaphragm anterior to the spleen and extending to, but not across, the muscle around the hiatus. The index and middle fingers of the left hand are passed through this incision into the hernia sac, which is divided 2 to 2 5 cm. from the cardia, medially, anteriorly and laterally. The remainder of the sac (attached to the margins of the hiatus) is excised. A traction tape around the esophagus is drawn down through the hiatus and then up through the incision in the diaphragm, so that when traction is applied the cardia is brought within the abdomen. The cut edge of the sac, including peritoneum and phrenicoesophageal ligament, is then sutured to the undersurface of the diaphragm anteriorly and to the left by interrupted silk sutures (Fig. 464). The posterior portion of the dome of the diaphragm is retracted forward so as to expose the posterior portion of the right crus. The esophagus is then drawn forward and the fibers of the right crus are approximated posterior to the esophagus by a few silk sutures (*Fig.* 465). These sutures must not be tied tightly for to do so would destroy the muscle function. The diaphragmatic and chest wall incisions are then closed. A soft rubber catheter may be inserted through one of the lower intercostal spaces for temporary underwater drainage.

Retrosternal diaphragmatic hernias (through the foramen of Morgagni) have a sac and usually contain both colon and omentum, sometimes only omentum. They are best approached through an upper rectus or midline incision or through a high transverse incision. The sac should be excised. Closure may be made in an

stomach tube should be passed before the closure is completed so as to avoid too great narrowing of the esophageal lumen. Harrington usually does a preliminary temporary paralysis of the left diaphragm.

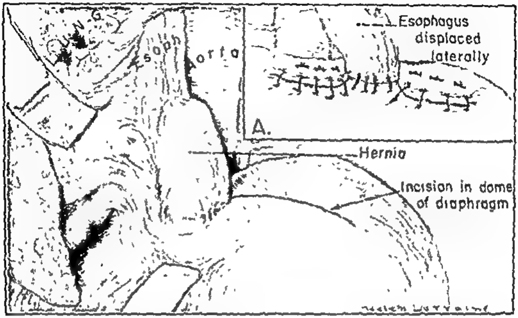


Fig. 462.—Modified Rives operation for the cure of paresophageal hiatus hernia. The esophagus is displaced laterally into the central tendon The esophagus is fixed to the peripheral end of the wound

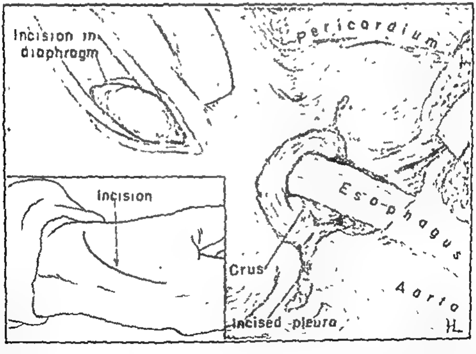


Fig. 463.—Allison's operation for sliding hiatus hernia The skin incision is shown in inset

Rives uses a posterolateral incision through the left eighth intercostal space or in the bed of the resected ninth rib. Upon entering the thorax he proceeds immediately to incise the diaphragm from the center of the dome through the lateral margin of the hiatus The index finger of the left hand is then inserted through this incision into the sac, which is dissected free and is completely excised. The

lower esophagus is then mobilized. If the esophagus is short, he sutures the stomach wall to the anterior, medial, and posterior margins of the hiatus. The greater curvature is sutured without constriction to the margins of the diaphragmatic incision. The remainder of the incision in the diaphragm is closed by imbrication with two rows of silk sutures. As indicated by this procedure, Rives believes symptoms are produced by the diaphragmatic constriction of the distended stomach. When the esophagus is of normal length, Rives transplants it laterally into the tendinous portion of the diaphragm and closes the medial portion of the opening by imbrication with silk sutures, thus placing the mobile fundus beneath the strongest section of the diaphragm. (Fig. 462.)

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anteroposterior direction or in the transverse plane. The latter closure is usually more easily accomplished because in the majority of cases the transverse is the greatest diameter of the ring. In this type of closure the anterior margin of the diaphragm is sutured to the anterior chest wall, then to the posterior sheath of the rectus muscle, by interrupted sutures of medium silk.

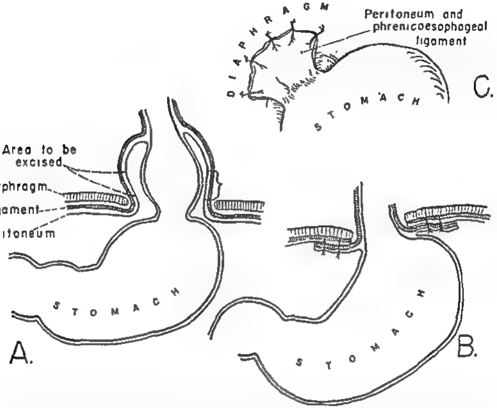

Fig. 464.—Repair of sliding hiatus hernia (Allison.) *A*, Cross section of hernial sac, showing area to be excised *B*, Upper portion of the sac and the phrenicoesophageal ligament sutured to the undersurface of the diaphragm. *C*, View from undersurface of diaphragm at completion of operation.

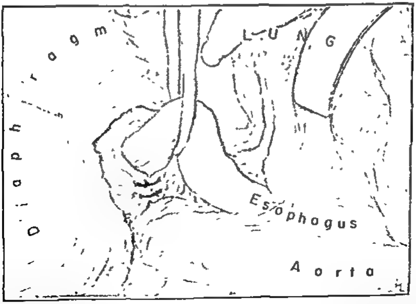

Fig 465—Allison's operation for sliding hiatus hernia. The fibers of the right crus of the diaphragm have been approximated posterior to the lower end of the esophagus.

If the opening through the diaphragm is an anteroposterior slit, the margins may be approximated in that direction with interrupted silk sutures. These hernias usually project to the right of the midline.

The posterolateral, pleuroperitoneal hernias (through the foramen of Bochdalek) may occur on either side. Those on the right usually involve the greater part of the liver as well as the large and small bowel; those on the left, the spleen, large bowel, and parts of the small intestine. Because of the amount of space occupied by these structures it is difficult, sometimes impossible, to replace them in the unopened abdomen, and the longer the operation is delayed, the greater this difficulty becomes. Infants with this type of hernia usually have serious respiratory, circulatory, and digestive disturbances and gain slowly if at all, and, as previously stated, many of them die during the first few weeks of life. For these reasons infants with large posterolateral diaphragmatic hernias should be operated upon promptly. Formerly operation was often postponed with the hope they would become better subjects for major surgery, but it is now realized that this usually does not happen, and, at any rate, infants only a few days of age withstand major surgery extraordinarily well.

Either a muscle-splitting rectus or a subcostal incision will give a satisfactory exposure for the reduction and repair of this type of hernia. Before an attempt is made to deliver the abdominal organs from the chest cavity, air must be admitted, otherwise suction will make this part of the procedure more difficult and more traumatizing Air is easily admitted by inserting a rubber catheter through the ring or by simply stretching the ring. The contents of the hernia are delivered onto the abdominal wall and carefully inspected, then covered with warm saline sheets. These hernias rarely have a sac, so the margins of the ring are excised and the opening is closed with interrupted silk sutures. This usually is not unduly difficult in infants because of the mobile lower chest wall.

When the repair of the diaphragm has been completed, the abdominal organs are placed within the peritoneum, often the most difficult part of the procedure. If, as is usually the case, difficulty is encountered in closing the deeper structures of the abdominal wall, it is wise to adopt the plan described by Ladd and Gross; that is, to close only the skin and subcutaneous tissue for the time being. For relaxation, the skin and subcutaneous tissue are separated from the fascia for a short distance on each side of the incision. It will be found that these structures can be closed without great difficulty, the subcutaneous tissue with continuous fine chromic catgut and the skin with interrupted sutures of fine silk. Six to eight days later the wound is reopened and closed in layers, usually without especial difficulty.

Hernias in this area are more difficult to repair in adults and it may be necessary to resect segments of several of the lower ribs to gain sufficient mobility of that portion of the wall to permit closure of the opening. For this and other reasons lateral hernias in adults are more satisfactorily repaired from above the diaphragm.

Eventration of the diaphragm may occur on either side, but is more frequent on the left. Since serious respiratory difficulty may result from this defect, an attempt should be made to fix the diaphragm at its proper level. That this is possible in some cases is indicated by reports of successful operations in the recent literature. Bisgard and Robertson reported a successful case in 1945, apparently the first surgical cure of this condition to appear in the literature. In this case the

right diaphragm was involved and produced serious respiratory difficulty. The child was operated upon at six weeks of age. The chest was opened through the ninth intercostal space and the diaphragm was plicated by three superimposed rows of interrupted silk sutures, thus fixing it at a normal level. Five months later the right diaphragm was one interspace higher than the left.

Whether or not a satisfactory repair can be obtained depends largely on the structure of the displaced diaphragm. If it appears to be too fragile for satisfactory repair, a flap of chest wall pleura and endothoracic fascia may be used to reinforce the repair. This should be done at a later date and through a fifth or sixth interspace incision. In all operations upon the diaphragm provision must be made for the maintenance of lung expansion by positive pressure. In infants this is best done by a small snugly fitting mask.

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CHAPTER 41

PERICARDIUM AND HEART

I. A. Bigger

The great majority of operations upon the pericardium are performed for hemopericardium, pericarditis with effusion, suppurative pericarditis, and constrictive pericarditis—conditions which produce cardiac compression.

Tumors of the mediastinum or lung may involve the pericardium by direct extension and require resection of considerable portions of that structure. Primary tumors of the pericardium are rare and are usually inoperable when discovered, but a small number have been successfully excised. In recent years, many surgeons have followed Allison's lead in ligating the pulmonary vessels intrapericardially when performing pneumonectomy in certain cases of carcinoma of the lung.

The procedures used for the relief of cardiac compression are pericardicentesis, pericardiostomy, and pericardiectomy.

PERICARDICENTESIS

Paracentesis of the pericardium when used as a diagnostic measure is of value, especially in patients suspected of having suppurative pericarditis. The two routes commonly used for aspiration of the pericardium are between the xiphoid and the left costal border, and through the left fifth intercostal space about 2 cm. from the sternal border. The left intercostal approach is the one most frequently used, but the risk probably is greater than by the subcostal route. The insertion of a needle into the pericardial sac is not an altogether safe procedure by any route. The chief dangers are injury to the internal mammary vessels which lie near the border of the sternum and injury to the coronary vessels or to the wall of the heart. Contamination of the pleura by passing a needle through the free pleural space also is a danger when aspiration is used as a diagnostic measure in patients suspected of having suppurative pericarditis. When the pericardium contains appreciable fluid, the heart occupies an anterior position and not infrequently is adherent to the anterior pericardium. When there is infection, anterior fixation of the heart makes it especially liable to injury when aspiration is attempted to the left of the sternum. Also, there is more likelihood of a dry tap by the intercostal approach. When aspirating the pericardial sac, certain precautions are necessary regardless of the route used. The plunger should be withdrawn slightly as soon as the needle appears to have entered a cavity; if the free pericardial sac is entered, fluid will be obtained promptly. If fluid is not obtained, and especially if pulsations are transmitted through the needle, it should be withdrawn.

For aspirating the pericardium by the left costoxiphoid route, the needl be passed upward and backward at an angle of 45 degrees with the ant dominal wall and should make contact with the posteroinferior border of costal margin opposite the xiphoid. If the needle is inserted at an angle to right angle, the peritoneal cavity may be entered, but with proper care thi not occur. There is but slight danger of injuring a coronary vessel; and, sir vessels are small near the cardiac apex, such an accident is of no great imp Also, the danger from injury to the heart wall is slight because of the thi culature near the apex. An added advantage of the subcostal route is needle enters the posterior portion of the pericardial sac where fluid usu cumulates.

PERICARDIOSTOMY

Although opinions differ as to the relative merits of repeated aspirati bined with the local and systemic use of antibiotics, and pericardiostomy, desirable to establish continuous drainage when the pericardium contains fluid. The danger of repeated pericardicentesis in the presence of infecti doubt as great, possibly greater, than that incident to pericardiostomy; antibiotics are apt to prove more effective when given in conjunction wi tinuous drainage. Furthermore, with continuous drainage the pericardiu tracts more rapidly, and more certainly obliterates the pericardial space, decreasing the danger of persistent or recurrent infection.

Numerous technics have been recommended for drainage of the peric but many of them are unnecessarily complicated. Adequate drainage may tained by resection of one or at most two cartilages to the left of the sternur fifth, or fourth and fifth, are best chosen because they overlie the so-call space and contamination of the pleura is less likely. As a rule, resection fifth cartilage will give sufficient exposure. The internal mammary ves divided between ligatures, the perichondrium and intercostal structures are at the sternum, and the loose tissue over the pericardium is stripped laterally ing the pleural fold with it. The pericardium is carefully opened in line v skin incision, and the purulent fluid is removed by suction The index f inserted, and adhesions between the pericardium and epicardium are sep pressure being applied against the parietal pericardium. When adheren have been separated, the margins of the pericardial incision are tacked to t toral fascia by a few interrupted sutures of plain catgut, and the skin and are loosely approximated by interrupted sutures on each side of the area supialization

Postoperatively, a well-lubricated, sterile-gloved finger, or soft cath passed around the heart each day until the pericardial space has been obliterated Drainage material is not left in the pericardial sac.

Pericardiostomy should be performed as soon as the fluid becomes purulent, for with early operation the heart muscle will receive less dama infected pericardium will contract more rapidly, and the infection will be le sistent. There is no contraindication to early open drainage of infection pericardium such as exists in acute empyema of the pleura.

Local infiltration and intercostal nerve block anesthesia should be used.

ADHESIVE PERICARDITIS

Two principal forms of adhesive pericarditis have been described: that which fixes the outer surface of the pericardium to the surrounding structures as well as its inner surface to the epicardium; and fibrous constricting pericarditis, which may or may not show fixation to adjacent structures. Formerly, it was thought that the first variety, so-called mediastinopericarditis, prevented complete cardiac systole, thereby reducing the output per beat. This, it was supposed, added appreciably to the work load of the myocardium, leading to hypertrophy and eventually to dilatation and failure. Experience, however, has shown that this condition almost never occurs as an entity, so the operation recommended for its relief, mobilization of the precordial portion of the chest wall, is rarely indicated. In concretio cordis, or fibrous constricting pericarditis, the heart is compressed as if in a vise, so that ventricular filling is incomplete and the output per beat is reduced. To complete the picture, it should be added that in constrictive pericarditis the diaphragmatic surface of the pericardium is generally firmly fixed to that structure, and this interferes with cardiac systole, especially during inspiration. It is apparent that the circulatory difficulty associated with constricting pericardities can be relieved only by excision of the fibrous, thickened pericardium.

PERICARDIECTOMY OR DECORTICATION OF THE HEART FOR CONSTRICTIVE PERICARDITIS

Even though fixation of the heart to the diaphragm has an adverse effect on the circulation, no appreciable improvement in cardiac function can be expected other than from excision of the dense scar which compresses the heart. Although excision of this scar is usually referred to as pericardiectomy, it is important to realize that the fibrinous deposit involves both pericardium and epicardium and, when organization takes place, these structures are covered by dense scar and may be indistinguishable the one from the other. Sometimes, between the pericardial and epicardial scar there will be a cleavage plane which can be misleading; at other times, the two surfaces are separated over considerable areas by collections of fluid. In either circumstance, it must be understood that removal of the outer layer alone will fail to give relief. A line of cleavage must be developed which will expose the myocardium; and, when the proper cleavage plane is entered, it will be noted that the wall of the heart bulges through almost immediately.

There is little unanimity of opinion as to the extent of scar which it is necessary to remove and as to which areas are most important to uncover. Holman insists that the anterior surface of the ventricles and all cardiac borders be liberated. He also stresses the importance of removal of scar from both venae cavae, and excision of the scar lying between the heart and diaphragm.

The present trend unquestionably is toward more extensive removal of scar and the results are frequently unsatisfactory when limited resections are done, especially when the venae cavae are not released. On the other hand, patients who have long suffered from marked cardiac compression may be unable to withstand so extensive an operation, and the atrophic myocardium may dilate if too widely uncovered. Under such circumstances, it may be well to plan a limited resection, partially releasing both right and left ventricles. Later, when the patient's condition has im-

proved sufficiently, a more extensive resection may be done. Admittedly such an operation may fail completely if there is constriction of one or both venae cavae.

Numerous approaches have been recommended and used for pericardiectomy. These include a transpleural approach through a left intercostal incision, and, sometimes, bilateral intercostal incisions. Beck and Griswold recommended an H-shaped incision. Median sternotomy, formerly recommended by Lilienthal and more recently by Holman, probably gives a more completely satisfactory exposure of the heart than any of the others Before the approach is decided upon, the patient's ability to withstand surgery should be carefully evaluated. If the patient appears to be a suitable candidate for an extensive operation under intratracheal anesthesia, the mid-sternal approach probably should be used, since it permits wide resection of the pericardium, including that overlying both venae cavae. Should the patient's general condition appear to contraindicate such extensive surgery, a curved left parasternal incision, similar to that formerly used in the Brauer cardiolysis, is satisfactory. The fact that through this approach the entire procedure may readily be carried out extrapleurally, under regional and local anesthesia, is worthy of consideration.

The mid-sternal approach, as modified by Holman, is carried out through a slightly curved incision eccentrically placed so as to prevent its lying immediately over the perpendicular section of the sternum. The incision extends from about 3 cm. below the sternal notch to near the mid-epigastrium. The soft tissues are separated from the anterior surface of the sternum, and the xiphoid is freed from its soft tissue attachments and is excised. The anterior mediastinal areolar tissue and both pleural folds are separated from the posterior surface of the sternum and the adjacent costal cartilages, upward to the first intercostal space. The internal mammary vessels should be protected, and the pleura is kept intact if possible. However, this is not always possible, especially on the right, so intratracheal anesthesia is advisable. The sternum is divided at the level of the second intercostal space, and the distal segment is split longitudinally. Sternal section may be satisfactorily accomplished in a number of ways: by using the Lebsche sternal knife, by bone-cutting forceps, or by a Gigli saw. The latter method seems safer and, altogether, more satisfactory.

After the pleura has been separated from the cartilages and ribs for some distance on both sides, a self-retaining retractor is used to spread the sternal segments. By alternately freeing the pleura and widening the sternal separation, one may avoid tearing the pleura While freeing the left pleural fold, an attempt should be made to identify and protect the phrenic nerve. The right phrenic nerve is less liable to injury but should be kept in mind during liberation of the venae cavae.

The primary incision in the pericardial scar is best made over the thick-walled left ventricle, well to the left of the anterior descending branch of the left coronary artery A perpendicular incision of moderate length is made with a sharp scalpel and carefully deepened until the myocardium is exposed. This should be done with great care for it is not always possible to identify muscle fibers immediately. If in doubt, the scar is carefully separated from the underlying tissue for a short distance on each side of the incision. If the proper plane has been reached, the heart wall will bulge into the incision (Fig. 466), and this will not occur until the proper plane has been entered. The incision is now lengthened, and separation of scar from myocardium is extended in all directions by combined blunt and sharp dissection. It is

essential that the dissection be done under direct vision, and therefore cross incisions are made at intervals to ensure this. *Particular care must be used* when the dissection is being done near important coronary vessels such as the anterior descending branch of the left coronary artery. Care also must be used if it is decided to remove the scar from the wall of the right auricle, and during the liberation of the venae cavae. The scar is usually more dense and more adherent in the area between the inferior border of the heart and the diaphragm than elsewhere.

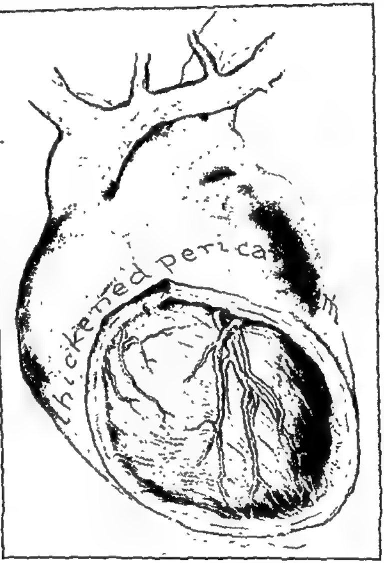

Fig. 466.—Area of greatly thickened pericardium excised from anterior surface of ventricles. Note bulging of heart wall.

Not infrequently the scar dips in between the muscle fibers and, if this is unrecognized one may be led into one of the heart chambers. If the dissection is done under direct vision with good lighting, these extensions of the scar should be recognized and divided by scalpel or scissors. Because of the danger of accidentally penetrating the heart wall and since the atrophic myocardium is extremely friable, it is best to leave a segment of pericardium attached in the area being dissected so that it may be used as a blowout patch. Frequently, there are areas of calcification in the scar, and these are especially prone to penetrate the myocardium. Complete removal under such circumstances is difficult and is attended by serious risk, so it

nay be wiser to leave such areas in place, completely removing all scar from around hem. Occasionally, a large proportion of the scar will become calcified and may ecome so dense as to require the use of bone-cutting forceps. It appears, however, hat the very extensively calcified scar rarely causes as marked cardiac compression s the more pliable fibrous tissue, and extensive removal may be unnecessary. Vhen sufficient scar has been excised, it may be advisable to make an opening into he right pleural cavity for drainage, since the extensive dissection leaves a large aw surface and a dead space where serosanguineous fluid often accumulates and auses tamponade if no provision is made for its escape. However, as a rule, a small Penrose drain brought out through a stab wound in the lower portion of the field vill suffice.

Closure is simple; the sternum is approximated with several sutures of stainless teel wire (30 gauge), passed around the sternum or through drill openings.

If the patient's condition contraindicates extensive surgery, the left parasternal xtrapleural approach is satisfactory. This approach lends itself well to the use of egional and local infiltration anesthesia, which is a decided advantage in especially oor-risk patients. The incision is made along the left sternal border from the econd intercostal space or third cartilage to the sixth cartilage, then out along the ixth intercostal space to the nipple line or beyond. The pectoral muscles are divided in line with the skin incision and separated from the underlying cartilages and nterior portions of the corresponding ribs, thus exposing the third, fourth, fifth, nd sixth cartilages. Resection of the third, fourth, and fifth cartilages may suffice, ut usually it is better to remove the sixth cartilage. The resection is done subperiosteally since it is no longer considered necessary to permanently mobilize the preordial portion of the chest wall. The internal mammary vessels are ligated above nd below, and the intercostal arteries are divided between ligatures. The interostal bundles and the periosteum are separated from the sternum. The left border f the sternum may be removed by rongeur, but the periosteum should be elevated nd preserved so that the intercostal muscles and periosteum may be sutured to it. The pericardium is exposed by incising the superficial areolar tissue at the sternal order, then carefully dissecting it laterally along with the left pleural fold. An attempt is made to identify and protect the left phrenic nerve. The exposure of the nyocardium and removal of the pericardial scar is executed in the same manner as lescribed in connection with the mid-sternal approach, except that the area of decortication is necessarily less extensive, usually being limited to the anterior surface f the ventricles, including the apex and the inferior cava

The incision is closed in layers with interrupted sutures

OPERATIONS UPON THE HEART AND THE ADJACENT PORTIONS OF THE GREAT VESSELS AT THE BASE OF THE HEART

The heart was the last important organ of the body to be approached surgically. This was due in large measure to the fact that the medical profession as well as the laity believed that wounds of the heart were necessarily fatal, so no attempt was made to repair them. In 1895 Del Vecchio demonstrated to the International Medical Congress, in session in Rome, that wounds of the heart in dogs healed satisfactorily when sutured During the following year (1896) three attempts were made to suture human heart wounds and one was successful.

Rehn operated upon a young man who had a penetrating wound of the anterior wall of the right ventricle and closed the wound by suture. The patient recovered. Since then hundreds of patients with heart wounds have been operated upon, apparently with increasingly good results. A large number of patients have also been operated upon successfully for the removal of foreign bodies from the heart. These results stimulated interest in the treatment of certain nontraumatic cardiac lesions by surgery.

The lesions of the pericardium, heart, and the great vessels at the base of the heart which have yielded the best results from surgical intervention are those amenable to extracardiac operations. Put differently, up to the present those lesions amenable only to intracardiac manipulation have in the main yielded less satisfactory results than lesions responsive to operations upon the pericardium or the great vessels. It is reasonable to suppose that this situation will continue until it is possible to shunt the circulation around the heart for a period sufficient for the performance of deliberate, carefully executed operations within the cardiac chambers. Gibbon, Dennis, Zollinger, and other investigators have continued their efforts in this difficult field in spite of obstacles which, to the uninitiated, seem almost insurmountable. Slow but steady progress has been made, so that success now seems assured. Much remains to be done, however, before a generally useful method is available for exclusion of the heart from the circulation. Even when this important goal has been attained, repair or replacement of certain structures such as the heart valves may pose a difficult problem.

Until it is possible to perform deliberate intracardiac procedures, it is unlikely that completely satisfactory results will be had in the treatment of conditions associated with intracardiac anatomic defects such as distorted heart valves. The achievements in this field during the past few years are truly remarkable, however, and intracardiac surgery which appeared well-nigh impossible only a few years ago is now being done. In 1929 Cutler and Beck made their final report on their attempts to relieve stenosis of the mitral valve by surgical means. These pioneers concluded that further efforts in that direction had best be deferred until developments in allied fields decreased the dangers incident to the undertaking. The work of Murray, Smithy, Harken, Bailey, and others, done in recent years under circumstances less difficult than those encountered by Cutler and Beck, has yielded far more encouraging results. The procedures designed by Brock for the relief of stenosis of the pulmonary valve and for infundibular stenosis, commonly a component of the tetralogy of Fallot, are ingenious, direct, and logical. Resection and dilatation for infundibular stricture or stenosis, it would seem, should produce more lasting results than the other intracardiac operations now being done. Unfortunately, the mortality so far has been distressingly high. While most intracardiac operations now being done are still in the developmental stage, a number of the extracardiac operations designed to relieve both congenital and acquired lesions of the heart, the pericardium, and the great vessels at the base of the heart are well established. The repair of heart wounds and excision of the constricting pericardium long have been accepted. Some of the procedures recently developed but of proved value are: closure of the patent ductus arteriosus (Gross), excision of the strictured area and end-to-end anastomosis for the relief of coarctation of the aorta (Crafoord, Gross, Blalock,) and the shunt operations (Blalock and Potts) for the relief of the cyanosis

associated with the tetralogy of Fallot. Also recently developed are procedures designed to relieve dysphagia and, on occasion, dyspnea, the result of anomalies of the aortic arch and its major branches (Gross).

A new technic is described for the removal of pulmonary emboli which appears to have decided advantages over those previously used The difficulty of accurate diagnosis, however, and the short time between the development of symptoms and death in patients with massive pulmonary emboli gives one little reason for optimism regarding the treatment of this deadly condition.

WOUNDS OF THE HEART AND INTRAPERICARDIAL PORTION OF THE GREAT VESSELS

Wounds of the heart may be nonpenetrating, penetrating, or perforating. Nonpenetrating wounds are usually the result of injury by blunt force and rarely necessitate operative intervention. There is the possibility, however, of rupture of one of the heart chambers, most likely one of the auricles, with the production of acute cardiac tamponade.

Penetrating wounds may result from bullets or pieces of shrapnel entering the chest and piercing one wall of the heart Under such circumstances, the patient may show signs of hemorrhage alone, but more often blood will be trapped by the pericardium, producing acute tamponade. The majority of penetrating wounds of the heart seen by surgeons are the result of stabbing with knives, ice picks, or similar weapons. One should add that surgeons rarely see penetrating wounds of the heart other than those which produce tamponade. Tamponade is in a sense a protective mechanism; but, like certain other protective mechanisms it will cause death if adequate treatment is too long delayed

Perforating wounds of the heart usually are the result of the passage of missiles, such as bullets or pieces of shrapnel, through both walls of the heart. Such wounds usually bleed profusely into one of the pleural spaces, producing the picture of hemorrhage and massive hemothorax Occasionally, however, when a ventricle is perforated, blood escapes from the heart more rapidly than from the pericardium and produces tamponade.

As previously stated, surgeons do not often see patients with heart wounds with free exit for the blood, for blood loss is so rapid and so great that death occurs within a few minutes. In those instances in which such patients survive to reach a surgeon, it is essential that the surgeon properly evaluate the situation, for immediate operation offers the only chance for survival.

When the opening in the pericardium is located behind the costal cartilages or sternum, it is apt to be displaced somewhat away from the opening in the chest wall when the pericardium is filled by the first rush of blood As the intrapericardial pressure increases, the opening in the pericardium is pressed against the rigid structures of the chest wall and the escape of blood is thus prevented The normal pericardium is a dense fibrous, relatively inelastic membrane which is not stretched appreciably by an acute increase in pressure, and not infrequently from 200 to 250 c c. of blood will cause sufficient tamponade to produce circulatory collapse. It is necessary that a clear distinction be made between circulatory collapse, the result of cardiac tamponade, and circulatory collapse from hemorrhage. In the former, blood is dammed up in the large venous reservoir and is immediately available to the cir-

culation upon release of the intrapericardial pressure. Consequently, the administration of large quantities of blood is unnecessary and unwise.

There has been a gradual, but decided, change of attitude toward the management of heart wounds with acute tamponade during the past decade. Following Rehn's successful cardiorrhaphy the medical profession soon came to believe that prompt surgical repair of heart wounds was necessary for recovery, and this belief persisted until within recent years. First Singleton, then Strieder reported the complete recovery of patients with tamponade following removal of the blood by needle aspiration. During recent years there has been an increasing number of such reports, and more recently both Elkin and Blalock have reported considerable numbers of patients with acute tamponade treated by pericardicentesis alone, with excellent results.

Fig 467.—Photograph showing the incision used for extrapleural repair of a wound of the left side of the heart Local anesthesia was used.

Apparently wounds of small to moderate size may become sealed off during the period of cardiac compression, and the majority of such wounds remain closed after the blood is removed by aspiration. This sometimes happens following surgical exposure of the heart, but more frequently bleeding is encountered when the pericardium is opened. This apparent discrepancy is probably due to the fact that manipulation incident to surgical exposure of the heart causes the wound to reopen. It would seem, therefore, that one should assume a more conservative attitude toward patients with heart wounds who show the characteristic signs of cardiac compression.

In patients with heart wounds and acute tamponade, we have, for a number of years, recommended the following plan of treatment: The initial treatment is the administration of morphine, 1/6 to 1/4 grain, atropine, 1/100 to 1/50 grain and

if the pulse is unduly slow, atropine, $\frac{1}{100}$ grain, is given intravenously. Five per cent dextrose in distilled water is given by venoclysis until blood is available. Pericardicentesis by the subcostal route is done promptly. If blood is removed, and tamponade is relieved, wait. If pericardicentesis is ineffectual because of clotting of the blood in the pericardial sac or if there is prompt recurrence of the signs of cardiac compression, immediate operation is indicated. It is advisable to leave the needle in place for the intermittent removal of blood while preparations are made for surgery.

The choice of a suitable approach is important in operations for the repair of heart wounds. If the evidence indicates that the wound is well over to the right side, especially if it is near the base of the heart, the approach should be on that side, through an interspace, in keeping with the level of injury. *In most circumstances the approach should be transpleural through an intercostal incision on the left side.*

If facilities for intratracheal anesthesia are available, ether and oxygen should be administered in that way. If such facilities are not available the operation may be performed under regional and local infiltration with procaine. Under these conditions, *the heart should be exposed extrapleurally through a curved left parasternal incision*, with subperichondrial resection of two or three cartilages, the third and fourth, or the third, fourth, and fifth (Fig 467). When intratracheal anesthesia is available, the heart is best approached through an intercostal incision extending from the sternum to the midaxilla, and at the level of the third, fourth, or fifth interspace, as seems indicated. *Adjacent cartilages may be divided at the sternum if wider exposure is needed.* The surgeon should make certain that he has an adequate exposure before he opens the pericardium, otherwise he may find himself in a difficult position if the exposure is inadequate and the bleeding profuse

CARDIORRHAPHY

In the presence of sufficient blood to cause tamponade, *the pericardium will be dark and tense.* After adequate exposure has been obtained, the wound in the pericardium is quickly enlarged, and a suction tube, with perforated guard, is inserted through the lower angle of the incision, into the posterior portion of the pericardial cavity. If the wound in the heart is of considerable size, it may be located by noting the point from which the blood is spurting. The hemorrhage is controlled by digital pressure until sutures can be inserted. If the wound is located anteriorly and is more than 2 cm in length, the technic suggested by Beck and Elkin is very satisfactory, namely, the passage of a deep suture beneath the compressing finger (Fig. 468) When possible, this suture should be inserted a considerable distance from the margins of the wound so that it will control hemorrhage more completely while the approximating sutures are placed. This first suture is used as a stay suture as well as a means of controlling hemorrhage. It is not tied and should be removed after the repair has been completed, for it is likely to penetrate the endocardium.

If the wound is lateral or posterior or, for any reason, difficult to expose, the apical traction suture suggested by Beck (1926) should be used (Fig. 468). A silk suture is placed through the thick muscle at the apex of the heart and grasped in the left hand while the left index finger is used to make pressure over the wound A deep approximating suture may then be inserted, or sutures may be placed on each side of the wound and parallel to it. Digital pressure is discontinued and

hemorrhage is controlled by crossing these lateral sutures while accurate approximating sutures are inserted and tied (Figs. 469, 470, and 471). The approximating sutures should be of 000 silk, threaded on curved French needles. They should approach the endocardium but should not penetrate it, for if exposed on the inside of the heart they may lead to thrombus formation. Interrupted sutures are preferable and should be tied only tightly enough to control hemorrhage and to

Fig. 468.—When a heart wound is lateral or posterior, a suture is placed in the apex of the heart and is held in the left hand of the operator for traction. The index finger of the other hand is placed over the wound to control the blood flow until a deep approximating suture is placed (Beck).

approximate the heart muscle. While the sutures are being inserted special care is taken to avoid injury to important coronary vessels. When the wound closely parallels an important coronary vessel, mattress sutures may be placed so that they pass underneath the vessel and, when tied, do not obstruct the lumen. If

bullet wounds of the heart, two wounds will usually be present, and this naturally increases the gravity of the prognosis. Under such circumstances the lateral control sutures for both wounds should be inserted before an attempt is made to place the approximating sutures.

In very large heart wounds it may be necessary to control hemorrhage by the maneuver described by Sauerbruch, while deep sutures are placed on each side. Sauerbruch advised passing the middle finger of the left hand through the great transverse sinus at the base of the heart, while the ring and little fingers were passed into the posterior portion of the pericardial cavity. In this way it is possible to compress the vena cava and pulmonary veins and temporarily control the flow of blood into the heart. This procedure is dangerous, however, and should be used only in

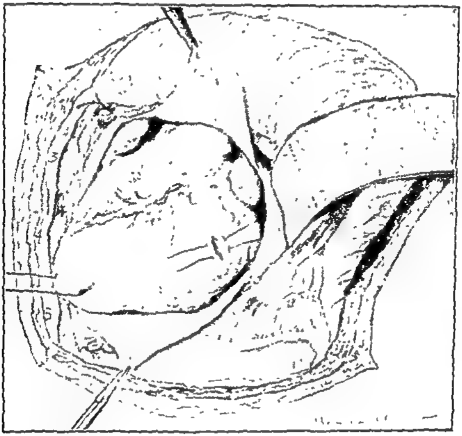

Fig 469 —Extrapleural repair of stab wound of the left ventricle.

the most urgent circumstances. If unusual torsion or traction on the heart is necessary to expose the wound, marked irregularities may develop, and occasionally the heart will stop beating. When the beat becomes irregular, it is necessary that traction be temporarily discontinued. In such cases a few cubic centimeters of 5 per cent procaine solution should be applied to the heart wall. Beck and Mautz showed that this helps prevent cardiac irregularities. Small quantities of procaine intravenously may better serve the same purpose. If the heart stops beating, it should be massaged. If it does not resume its beat promptly, 3 to 5 minims of 1:1000 adrenalin solution may be injected into the right ventricle

After the repair has been completed, the pericardial sac is flushed out with warm normal saline solution, and the margins of the stab wound in the pericardium and chest wall are excised The pericardial incision is approximated with widely

spaced interrupted sutures. A small Penrose drain may be carried down to the wall of the pericardium but not into the pericardial cavity. It should be removed within twenty-four hours. The incision in the chest wall is approximated in layers.

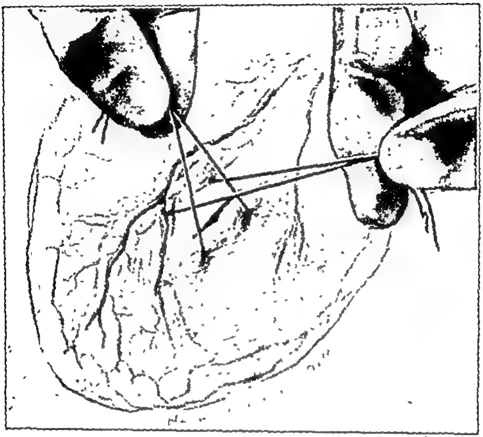

Fig. 470.—Two deep sutures are placed parallel to the long axis of the wound. These are crossed and made taut, thus controlling hemorrhage while the approximating sutures are inserted. (Beck.)

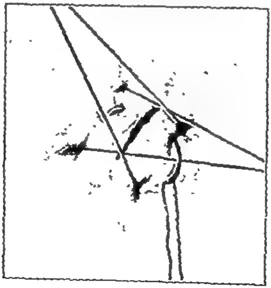

Fig. 471.—Interrupted sutures are then placed to approximate the wound edges.

OPERATIONS FOR FOREIGN BODIES IN THE HEART

Foreign bodies may enter the heart by direct penetration of .'
or they may enter one of the large veins and be carried to one of

bullet wounds of the heart, two wounds will usually be present, and this naturally increases the gravity of the prognosis. Under such circumstances the lateral control sutures for both wounds should be inserted before an attempt is made to place the approximating sutures.

In very large heart wounds it may be necessary to control hemorrhage by the maneuver described by Sauerbruch, while deep sutures are placed on each side. Sauerbruch advised passing the middle finger of the left hand through the great transverse sinus at the base of the heart, while the ring and little fingers were passed into the posterior portion of the pericardial cavity. In this way it is possible to compress the vena cava and pulmonary veins and temporarily control the flow of blood into the heart. This procedure is dangerous, however, and should be used only in

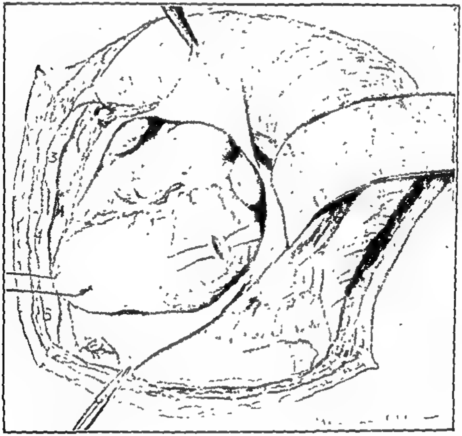

Fig. 469.—Extrapleural repair of stab wound of the left ventricle.

the most urgent circumstances. If unusual torsion or traction on the heart is necessary to expose the wound, marked irregularities may develop, and occasionally the heart will stop beating. When the beat becomes irregular, it is necessary that traction be temporarily discontinued. In such cases a few cubic centimeters of 5 per cent procaine solution should be applied to the heart wall. Beck and Mautz showed that this helps prevent cardiac irregularities. Small quantities of procaine intravenously may better serve the same purpose. If the heart stops beating, it should be massaged If it does not resume its beat promptly, 3 to 5 minims of 1·1000 adrenalin solution may be injected into the right ventricle.

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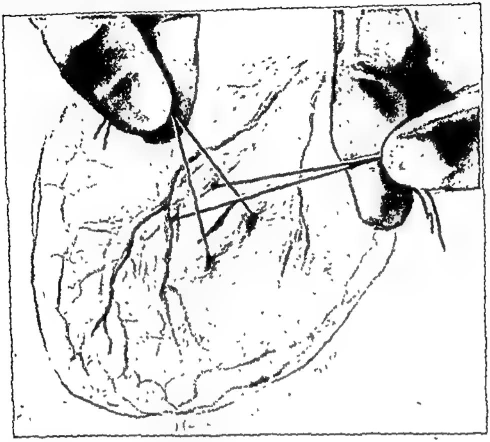

Fig. 470.—Two deep sutures are placed parallel to the long axis of the wound. These are crossed and made taut, thus controlling hemorrhage while the approximating sutures are inserted. (Beck.)

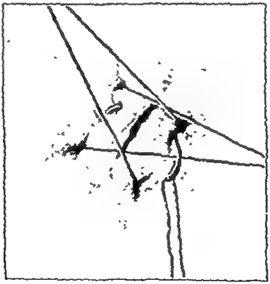

Fig 471 —Interrupted sutures are then placed to approximate the wound edges

OPERATIONS FOR FOREIGN BODIES IN THE HEART

Foreign bodies may enter the heart by direct penetration of the thoracic wall or they may enter one of the large veins and be carried to one of the cardiac cham-

bers. Those foreign bodies entering by direct penetration of the thoracic wall may lodge in the pericardium, the pericardial cavity, the wall of the heart, or in one of the cardiac chambers. Missiles of considerable size, bullets for instance, will usually lead to intrapericardial hemorrhage with cardiac tamponade or to massive hemorrhage into one of the pleural cavities. In either event operation is indicated. Unless the patient's condition is sufficiently serious to make immediate operation necessary, an attempt should be made to localize the foreign body accurately so that it can be removed without unnecessary manipulation and trauma. The approach is the same as for a heart wound without a retained foreign body. After exposure of the heart and control of hemorrhage, the foreign body is located and fixed between the middle and index fingers of the left hand, while sutures are inserted on each side of it, as suggested by Beck in wounds of the heart. An incision is made over the object, which is grasped by forceps and removed Hemorrhage is controlled by crossing the lateral sutures while the approximating sutures are inserted. Even though the missile is lodged in the heart wall, lateral sutures should be placed before it is removed, as it may have penetrated the endocardium. When foreign bodies are found within one of the cardiac chambers, Beck has suggested that mattress sutures be passed through both walls of the heart, on each side of the foreign body, thereby fixing the object in place and reducing the blood loss during its extraction. Small caliber objects, such as needles, may be extracted without preliminary exposure of the heart if they project above the skin surface, but the patient should be observed carefully for at least twenty-four hours because of the danger of the development of tamponade. Larger weapons such as knife blades, crochet needles, etc., should not be removed until the heart is exposed sufficiently to suture the wound after the foreign body is withdrawn If this precaution is not observed, serious hemorrhage may occur before the cardiac wound can be exposed.

One of the most interesting problems in connection with foreign bodies in the heart is the proper treatment in those cases in which foreign bodies enter the large veins and are then transported to the heart. The entrance may be by way of one of the large peripheral veins, the object passing through the right auricle into the right ventricle. It may remain in the ventricular cavity or may finally come to rest in a branch of one of the pulmonary arteries. Missiles penetrating the thorax may enter a pulmonary vein and be carried through the left auricle to the left ventricle, where they may remain, or they may be forced out through the aorta and come to rest in one of the peripheral arteries The indications for operation in such cases are not clearly defined.

Lockwood suggested the removal of foreign bodies which lodge in the right ventricular cavity, for he said that if they are thrown out into the pulmonary artery they may occlude a large branch of this vessel, with a fatal result. He advised, on the other hand, that foreign bodies in the left ventricle be not operated upon too precipitately but that they be given an opportunity to pass out into a peripheral artery from which they could be removed more safely. The decision as to the plan of procedure with a foreign body in one of the ventricular cavities will depend, of course, upon many factors, such as the size and nature of the body, the condition of the patient, and the associated injuries; but, in general, it would seem that when a small or medium-sized metallic body is found in the right ventricular cavity, an attempt should be made to displace it into the pulmonary artery, where it could be

left for the time being, to be removed later should conditions warrant it. There is considerable experimental evidence to indicate that this is a logical thing to do when foreign bodies enter the right ventricle through one of the great veins. Warthen (1927) showed that metallic objects in branches of the pulmonary artery were well tolerated in dogs. Many experimenters have introduced bodies of various types into the pulmonary circulation of dogs by way of the external jugular vein and have found that those of small or moderate size are well tolerated.

It may well be that it is advisable to attempt to dislodge medium and small foreign bodies from the left ventricle into the aorta, but, should they enter one of the carotid arteries, the situation probably would be more dangerous than that which previously existed.

In spite of the quite considerable experience during World War II with foreign bodies in and around the heart, clear-cut indications for treatment are not yet established. Harken indicated that something less than one-half the patients sent to the 160th General Hospital in England for foreign bodies in the cardiac area were operated upon. Large and especially irregular objects should be removed. The removal of smaller objects should depend to a considerable extent on whether or not they produce symptoms. Foreign bodies in the pericardium or heart should be removed at once only if operation is made necessary by hemorrhage or tamponade.

OPERATIONS FOR CORONARY SCLEROSIS AND ANGINA PECTORIS

Revascularization of the Heart; Cardiac Neurectomy

Coronary sclerosis is one of the most common as well as one of the most serious pathologic conditions occurring in persons past middle life, and up to the present time its treatment has been extremely unsatisfactory.

The surgical approach to this problem has been directed mainly along three lines:

1. Interruption of the sympathetic and/or parasympathetic nerve connections with the heart.

a. Stellate ganglionectomy (Leriche).

b Upper dorsal sympathectomy (White).

c. Resection of the preaortic nerve plexus, thereby interrupting both sympathetic and parasympathetic nerve connections with the heart (Lian).

2. Revascularization of the heart (Beck).

a. Transplantation of various tissues such as pectoral muscle, mediastinal fat, and internal mammary vessels for the production of extracoronary collateral anastomoses.

b. The production of an inflammatory reaction over the surface of the heart for the production of intercoronary anastomoses. This is accomplished by trauma to the serous surfaces of the pericardium and epicardium plus the application of an irritant such as asbestos powder (0.2 Gm.).

c. Anastomosis of the aorta to the coronary sinus, by vein graft, thus converting the coronary sinus functionally into an artery. The cardiac segment of the sinus adjacent to the auricle is partially obstructed at a second operation.

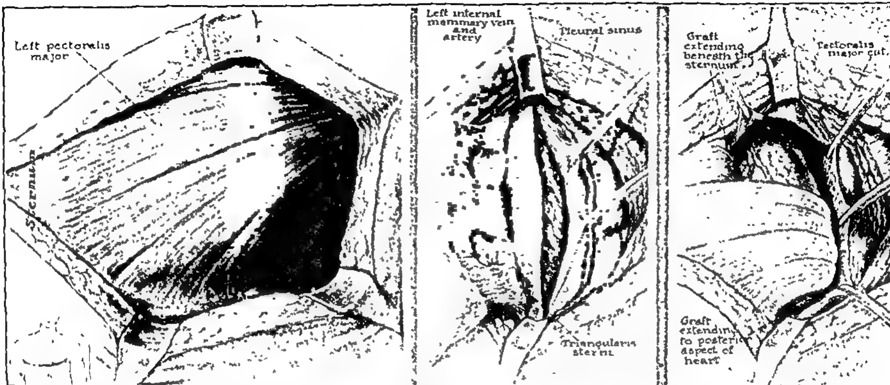

Fig. 472.—Modification of Beck's original operation. A transverse incision is made from the right border of the sternum to the left nipple. The superficial tissues are dissected from the inferior portion of the left pectoral muscle and this muscle is then divided in the lateral portion of the field. Two flaps are formed by splitting the muscle in line with the fibers. The smaller flap is inserted beneath the sternum in contact with the anterior surface of the right ventricle and the larger flap is inserted around the left border of the heart in contact with the circumflex area of the left ventricle. (Beck, 1936.)

3. Interruption of the sympathetic and parasympathetic connections with the coronary vessels and ligation of the great coronary vein.

Revascularization of the heart is more direct and therefore makes a greater appeal, since it is directed toward relief of the fundamental problem in coronary artery disease and angina pectoris—ischemia of the myocardium. However, it must be admitted that there are many difficulties to be overcome before an entirely satisfactory solution to the problem can be achieved by this approach. Methods directed toward the development both of extracoronary and intercoronary anastomoses have to contend with the formation of scar tissue and the gradual reduction of vascularity by this scar.

In 1932 Beck began experiments directed toward the development of a collateral blood supply to the heart, with the idea that it might be possible to replace the coronary circulation when the coronary vessels gradually became occluded. In his experiments he found that a satisfactory collateral vascular bed could be developed only when the coronary arteries had been partially occluded; in other words, when there was a physiologic need for additional blood supply to the heart. After partial occlusion of the coronary arteries in dogs, satisfactory anastomoses could be established between the vessels of transplanted pectoral muscles or omentum and the coronary vessels. Because of the technical difficulties of bringing the omentum through the diaphragm, it was decided to use pedicled flaps from the pectoralis major muscle.

The first operations designed by Beck for the promotion of extracoronary communications (Fig. 472) were accompanied by a high mortality, 37.8 per cent (Feil), but the mortality probably can be reduced by a better selection of patients and by simplification of the technical procedure. Better selection of patients would be the natural result of greater experience.

The procedure used by Beck in his later cases was less extensive than that used on his first group of patients. It is, in brief: a curved left parasternal incision extending across the sternal end of the fourth, fifth, and sixth costal cartilages, then curving out along the sixth cartilage and rib; resection of these cartilages and the anterior ends of the corresponding ribs; and entrance through the pleura in the areas from which the cartilages had been removed. The internal mammary and intercostal vessels are carefully protected. The pericardium is sutured to the chest wall, opened, and the serous lining of the pericardium is roughened by a specially constructed burr, and asbestos powder, 0.2 Gm., is applied to the pericardial and epicardial surfaces. Mediastinal fat and the internal mammary and intercostal vessels are placed in close contact with the heart; the pericardium is not closed. The chest wall muscles, fascia, and skin are closed in layers.

This procedure is simple and should not give a high mortality in patients with moderately advanced coronary disease. Almost any such undertaking will show a high mortality in patients with far-advanced coronary disease, but, as Feil points out, such patients should not be operated upon, for even those who survive are not often improved. At any rate, Beck has, at least for the time being, discarded the procedure and is directing his energies toward attempts to utilize the coronary sinus as an artery for transport of blood to the myocardium. Efforts to arterialize the coronary sinus may have a better chance of success than would attempts at reversal of the blood flow through veins of other organs or parts of the body, be-

cause of the anatomic peculiarities of the cardiac venous system. Beck's early results are most encouraging. However the procedure is still in the investigative or formative stage and should be so considered.

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CHAPTER 42

RESECTION OF THE AURICULAR APPENDAGES FOR THE PREVENTION OF ARTERIAL EMBOLISM; PULMONARY EMBOLECTOMY; CARDIAC RESUSCITATION; THE SURGERY OF ACQUIRED VALVULAR DISEASE

RESECTION OF THE AURICULAR APPENDAGES FOR THE PREVENTION OF ARTERIAL EMBOLISM

I. A. Bigger

Madden, and Beal, Longmire and Leake, and others have reported resection of the auricular appendages for emboli, peripheral or pulmonary, in patients with auricular fibrillation. Beal, Longmire, and Leake entered the chest through the third intercostal space for resection of the auricular appendages. This approach proved satisfactory on the left side, but was less satisfactory on the right because the right auricular appendage lies anteriorly beneath the sternum.

A mid-sternal incision curving to the right at the level of the third costal cartilage probably would give a more adequate exposure. For this approach a segment of the third cartilage is resected subperiosteally, and a narrow segment of the sternum is then removed by rongeur at the junction of the third cartilage with the sternum. The loose tissue is separated from the posterior surface of the sternum up to the sternal notch and the upper segment is sectioned longitudinally by a Gigli saw. The sternal segments are widely separated by a small rib-spreading retractor, giving an excellent exposure of the pericardium over the right auricular appendage.

The pericardium is widely opened in the perpendicular direction by a curved incision, convex laterally; the tip of the appendage is gently grasped to steady it and a long-bladed right-angled noncrushing clamp is applied across the base of the appendage. The walls of the appendage are then approximated by a continuous mattress suture of silk, which is tied at each end This suture line is placed immediately lateral to the clamp, the appendage is partially divided lateral to the first suture line, and the cut edges of the walls of the auricle are approximated by a continuous over-and-over silk suture; the remainder of the appendage is divided, and the second line of suture is completed. The clamp is removed, and if there are areas of seepage they are controlled by interrupted sutures. The pericardial incision is loosely approximated by widely spaced interrupted sutures.

The indications and contraindications for excision of the auricular appendages are not yet clearly established, but when an individual with persistent auricular fibrillation and no evidence of myocardial infarction shows peripheral arterial em-

boli, excision of the left auricular appendage should be given consideration. The indications for right auricular appendectomy are even less definite, but repeated pulmonary embolization in the absence of demonstrable thrombosis of the peripheral veins points to the right auricle as the probable source of the emboli.

PULMONARY EMBOLECTOMY

I. A. Bigger

In 1908, Trendelenburg reported the first removal of an embolus from the pulmonary artery. Twelve such operations were performed in his clinic, but in no case was there a permanent recovery. The first successful pulmonary embolectomy was performed by Kirschner in 1924, and in 1930 Nystrom was able to find reports of only fourteen cases in which the patient had survived the operation and only seven in which there was a permanent recovery. Two of these patients were operated upon by Nystrom, two by A. W. Meyer, two by Crafoord, and one by Kirschner. In all of these operations, it was necessary to bring the circulation to a standstill, an extremely serious matter.

The Left Pulmonary Artery Approach for Pulmonary Embolectomy

Harken and Bigger, independently of each other, have developed a technic for pulmonary embolectomy which has a number of advantages over the technics previously used. The most important advantage lies in the fact that it is not necessary at any time during the operation to occlude either the main pulmonary artery or the aorta. Another advantage is that the flow of blood assists in removing the clot, whereas, with approach through the first portion of the main pulmonary artery or through the wall of the right ventricle, the blood current increases the difficulty of clot extraction.

Operative Technic

An incision is made over the left third rib and cartilage from the sternum to the anterior axillary line or beyond, and the pectoralis major muscle is incised in line with its fibers. The third cartilage and rib are resected subperiosteally from the sternum to the midaxilla. The second and fourth cartilages are divided at the sternum and the left chest cavity is entered through the bed of the third rib. With the rib-spreading retractor one obtains an excellent exposure of the mediastinal structures (Fig. 473.) The pericardium is incised perpendicularly in its upper third over the distal segment of the main pulmonary artery and the incision is carried to the extreme upper limit of the pericardial extension along the pulmonary artery. The incision is continued laterally through the mediastinal pleura along the course of the left pulmonary artery to the lung margin. The left pulmonary artery is rapidly separated from the other hilar structures and heavy catgut or narrow tape is placed around it for traction Four silk traction sutures are now inserted, two on each side, near each end of the proposed incision in the left pulmonary artery. This should be made on the anterior surface of the artery and should start about 1.5 to 2 cm. from the origin of the left pulmonary artery and extended distally for 1 5 cm.

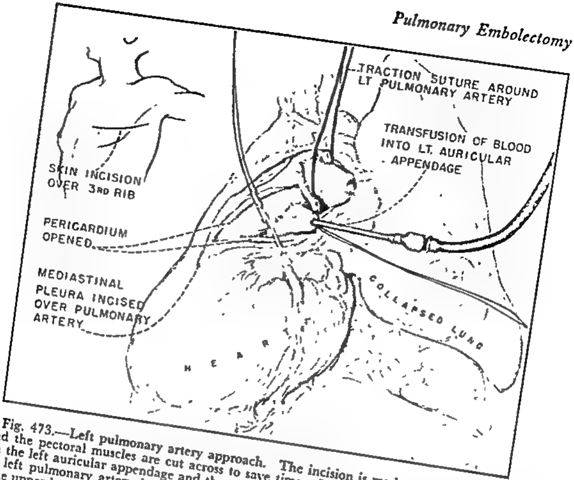

Fig. 473.—Left pulmonary artery approach. The incision is made directly over the third rib and the pectoral muscles are cut across to save time. The pericardium is opened widely to expose the left auricular appendage and the origin of the left pulmonary artery. The remainder of the left pulmonary artery is rapidly exposed by curving the incision in the pleura laterally over the upper border of the lung root.

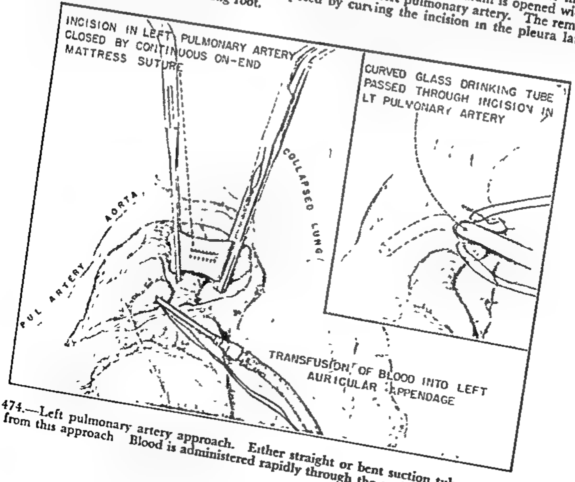

Fig 474.—Left pulmonary artery approach. Either straight or bent suction tube may be used from this approach Blood is administered rapidly through the auricular appendage.

Before the artery is opened, a silk purse string is placed around the tip of the left auricular appendage and a large size (8 or 10 gauge) cannula is inserted and fastened in place by the purse string.* Blood is rapidly administered into the auricle as there is rapid blood loss during the next stage of the procedure.

The incision is now made as outlined by the traction sutures and a large-sized bent glass drinking tube (Fig. 474), connected with suction, is immediately inserted and is passed into the main pulmonary artery, then into the right main pulmonary artery, and finally is turned distally into the left pulmonary artery. It is withdrawn after an excursion into each division of the pulmonary artery, and if clot is obtained, that segment is again explored. If the clot is at all fragmented, parts of it will be extruded through the incision when the tube is withdrawn between exploratory excursions. When no additional clot is obtained, a clamp (the ingenious ductus clamp devised by Potts is ideal) is placed across the left pulmonary artery at its origin. Distal occlusion may be achieved by another clamp or by traction on the tape. The incision is then closed by a continuous everting mattress suture of four 0 or five 0 silk and the obstructing clamps are removed.

A rather large amount of blood is lost during the time necessary for clot removal, but since it is replaced almost as rapidly as it is lost, it is not of too great importance. The blood removed from the pulmonary artery and that escaping into the pleural cavity should be suctioned into a sterile jar containing sodium citrate solution, to be used for autotransfusion. When sufficient blood has been given into the auricle to bring the pressure to a near normal level, the cannula is removed and the opening is closed

The second and fourth cartilages are sutured to the sternum with 32 gauge stainless steel wire. The bed of the third rib is closed by sutures through the pleura and periosteum. One intercostal drainage tube may be left in for twenty-four to forty-eight hours.

CARDIAC RESUSCITATION

FRED WALLS

With the apparent increase in the incidence of cardiac arrest and ventricular fibrillation, the surgeon and the physiologist have shown more interest in cardiac resuscitation. This has resulted in the development of preventive measures and measures for resuscitation. While this discussion is limited almost exclusively to resuscitation, it would be incomplete were the importance of the prevention of anoxia not emphasized, since anoxia probably is the most important cause of cardiac arrest and ventricular fibrillation.

In cardiac arrest there is complete cessation of all myocardial activity. In ventricular fibrillation there is an increase in ventricular activity but the contractions are asynchronous and ineffective so that there is no cardiac output. Either of these conditions may occur suddenly and unexpectedly in any stage of anesthesia but they are especially prone to develop during the induction period and under light anesthesia. Unless corrective measures are promptly instituted, a fatal outcome is certain; consequently, for successful handling of these emergencies, there must be an established plan of action which can be initiated without delay.

*Suggested by Dr. William B. Porter (personal communication)

When there is evidence that either cardiac arrest or ventricular fibrillation is present, the heart should be exposed immediately. The delay occasioned by trying to detect the heartbeat with a stethoscope or by obtaining an electrocardiogram may prove disastrous. The heartbeat which requires detection by these means, in the absence of demonstrable pulse or blood pressure, is of little consequence. Dilatation of the rectal sphincter, arterial transfusion, or the intracardiac injection of epinephrine through the chest wall are of uncertain value and usually lead only to further delay. It is imperative that an adequate circulation be restored within three to five minutes after the onset of cardiac arrest or ventricular fibrillation; otherwise, death or mental deterioration from anoxia of the central nervous system is inevitable.

Two things are essential in connection with cardiac resuscitation, maintaining an adequate circulation and making oxygen continuously available for transportation to the tissues.

It is the responsibility of the anesthetist to have a suitable intratracheal tube available at all times and to insert it at once should cardiac standstill or ventricular fibrillation occur. With the intratracheal tube in place, the anesthetist rhythmically inflates the lungs with 100 per cent oxygen by compression of the anesthesia bag. A mechanical respirator, although not essential to successful resuscitation, is ideal for the purpose because it assures respirations of constant depth and rate and frees the anesthetist for the performance of other duties.

The heart is best exposed through the left fourth or fifth interspace, the incision extending from the sternum to the midaxillary line. Additional exposure may be obtained by severing one or more costal cartilages at the sternum. A rib-spreading retractor is helpful but not essential. Asepsis must be disregarded if sterile equipment is not immediately available. Sterile equipment may be substituted after the emergency has been met. Bleeding causes no delay since there is no blood pressure. However, it may be necessary to ligate the internal mammary or other large vessels after intermittent cardiac compression has been instituted.

Cardiac compression may be applied through the intact pericardium but is accomplished more effectively with the pericardium widely opened. The optimum rate of compression has not been established with certainty, but 40 to 60 times a minute has proved effectual. When an adequate circulation has been reestablished by intermittent compression of the heart, and oxygen is being administered through a proper airway, haste is no longer necessary. After a short time, manipulation of the heart should be interrupted long enough to see if it will contract spontaneously. The technic used in compressing the heart is to some extent a matter of individual preference. Some surgeons feel that they produce a more effective cardiac output by compression of the heart against the sternum, whereas others apparently obtain better results by compressing the heart in the palm of the hand, with the fingers encircling the posterior surface, and the thumb and thenar eminence the anterior surface. The size and shape of the hand are no doubt of importance in this connection. The purpose of intermittent cardiac compression is the propulsion of blood throughout the body. To accomplish this purpose, it is essential that both ventricles be emptied as completely as possible and that an adequate rate of compression be maintained. Systolic pressures of 60 to 70 mm. Hg can be obtained, and this is sufficient to prevent serious cerebral anoxia.

Since the methods of restoring the heartbeat differ in cardiac arrest and ventricular fibrillation, it is necessary to be certain which condition is present. In cardiac

arrest there is complete absence of muscular movement, whereas in ventricular fibrillation there are uncoordinated fine fibrillary movements of the ventricular musculature.

In cardiac arrest it usually is possible to restore a normal beat by intermittent compression of the heart, providing oxygenation is adequate. If the heart fails to resume a normal beat with these measures, 3 to 5 c.c. of a dilute solution (1 mg. in 9 c.c. saline) of epinephrine are injected into one of the atrial or ventricular cavities through a small-bore needle, while massage is continued. When the injection is made into a ventricle, there is danger that this stimulus may produce ventricular fibrillation if the myocardium is anoxic. This danger is less when an atrium is the site of injection because the myocardium of its walls is less irritable. If, after three minutes, the heart still has not resumed a normal beat, epinephrine is again injected.

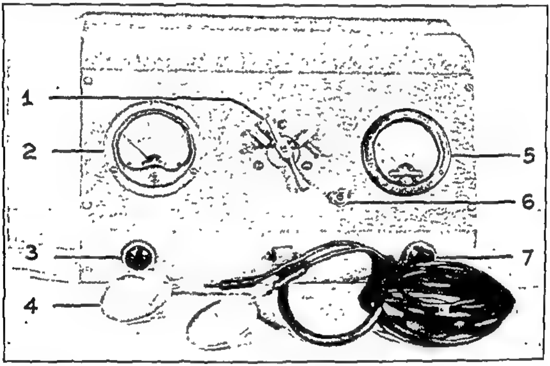

Fig. 475.—Electrical defibrillator. *1,* Selsyn transformer control. *2,* Ammeter. *3,* Current inflow indicator. *4,* Silver electrodes. *5,* Voltmeter. *6,* Toggle switch. *7,* Current outflow indicator.

Assuming that resuscitative measures have been established soon enough, continued *failure to respond usually indicates that the technic is in some way faulty.* The lungs must be well inflated and deflated with each respiration. Inadequate respiratory exchange has a distinctly adverse effect upon resuscitation. Repeated injections of epinephrine may be necessary before resuscitation is achieved, but one must exercise caution in this respect because the heart muscle becomes excessively irritable from overdosage with this substance. If the heart fails to resume a normal beat after several injections of epinephrine, an electrocardiogram should be obtained to eliminate the possibility of ventricular fibrillation, which may not be detected by simple observation.

The occurrence of ventricular fibrillation calls for additional measures. Although defibrillation has been accomplished by other means, the application of an electric shock directly to the heart has proved more effective than other measures

in restoring normal cardiac contractions. After the tissues have been assured an adequate supply of oxygen by artificial respiration and intermittent cardiac compression, two silver electrodes (Beck's) are placed on the heart, one against the anterior surface and one against the posterior surface, and a 110 volt alternating current of 1.0 to 1.5 amperes is delivered to the heart for a fraction of a second (Fig. 475). The shock is repeated in two to three seconds if necessary. If the heart fails to resume a normal beat after the second shock, massage is continued and 5 c.c. of 1 per cent procaine solution are injected into one of the cardiac chambers and the heart is massaged for two to three minutes to insure adequate circulation of the procaine through the myocardium. The shock is then repeated. It may be necessary to repeat the injection of procaine and the shock several times. Failure to defibrillate by these efforts usually indicates that the heart is in a state of atonic fibrillation. In this state the heart is soft and flabby and defibrillation cannot be accomplished. A state of convulsive fibrillation must be established and this may be accomplished by the injection of dilute epinephrine or calcium chloride solution into one of the cardiac chambers. If the heart regains its tone, the shock is repeated. Failure to defibrillate may be due to faulty technic. The current, to be effective, must traverse the entire myocardium. Caution should be exercised in the administration of procaine and epinephrine since an imbalance between the two may result in failure of resuscitation. The smallest dosages which will produce the desired physiologic response should be used.

Resuscitation efforts should be continued almost indefinitely, as long as an adequate supply of oxygen can be maintained. Rhythmic contractility is an inherent quality of the heart muscle and with proper treatment the beat usually can be restored.

THE SURGERY OF ACQUIRED VALVULAR DISEASE

LEWIS H BOSHER, JR.

At present the accepted surgery of acquired valvular disease is limited to the treatment of mitral stenosis. Early attempts at the surgical correction of mitral stenosis failed chiefly because the valvulotomy substituted a severe degree of regurgitation for stenosis. Recent contributions by Bailey and by Harken have renewed interest in this field. Valvuloplasty or commissurotomy along the line of pathologic fusion of the valve leaflets, that is, along the "commissures," bivalves the stenotic valve without introducing significant regurgitation. By improving the mobility of the rigid stenotic valve and permitting the leaflets to approximate more completely, existing regurgitation is sometimes eliminated. The operation devised by Sweet which establishes a shunt between the pulmonary and azygos veins reduces pulmonary hypertension and ameliorates the symptoms of dyspnea, hemoptysis, and pulmonary edema but fails to improve cardiac output. The Sweet operation should be reserved for those few cases in which commissurotomy is found to be anatomically not feasible.

The limitations of mitral commissurotomy are at present only vaguely defined. Dyspnea, serious restriction of activity, peripheral embolization, and episodes of pulmonary edema and hemoptysis signifying pulmonary hypertension constitute the chief indications for surgery. The obvious contraindications to operation may be

listed as follows: (1) active rheumatic myocarditis, (2) subacute bacterial endocarditis, (3) uncontrollable cardiac failure, (4) significant mitral regurgitation or associated aortic valvular disease with left ventricular enlargement. While increasing the risk somewhat, auricular fibrillation or a history of peripheral emboli should not deter the surgeon. The pathologic changes in the stenotic valve will determine to a considerable extent the technical success of the commissurotomy. In the presence of marked rigidity and extensive calcification the results will be less satisfactory.

The immediate symptomatic relief achieved by mitral commissurotomy has justified the operative procedure. Physiologic studies also demonstrate improvement of the cardiac output, particularly after exercise, and lowering of the pulmonary artery pressure. To what extent permanent pulmonary vascular changes may interfere with the success of the operation is not yet clearly defined. Undoubtedly the operation should not be delayed until significant organic changes have taken place in these vessels. Further observation may indicate the advisability of performing the operation earlier to avoid these and other irreversible changes. However, the degree or duration of mitral stenosis does not correlate well with the pulmonary vascular changes observed at postmortem. Specialized studies such as cardiac output and pulmonary artery and capillary pressure determinations, before and after exercise, should prove helpful in selecting these patients.

The anesthetic problems are related chiefly to reduced cardiac output and pulmonary hypertension resulting from mitral valve obstruction and to increased irritability of the heart. As advised by Harken, extreme tachycardia which threatens to precipitate pulmonary edema is controlled by intravenous Prostigmin. Because of the excessive irritability of the mitral heart and because of the contemplated manipulations, intravenous procaine is probably advisable as a prophylactic measure. Additional procaine may be used locally as required to control arrhythmias Large doses of these drugs, however, depress the myocardium and may seriously reduce cardiac output. Adequate preparation must be made for the rapid introduction of blood to replace sudden large blood loss during operation. Because of the inability of many mitral hearts to augment the cardiac output above a resting level, intra-arterial transfusion finds a special usefulness in temporarily combating severe hypotension in these patients.

The operative approach is through a left posterolateral incision, resecting the fifth rib. The pericardium is incised posterior to the phrenic nerve and an excellent exposure of the auricular appendage is obtained. Stay sutures inserted into the edges of the pericardial flaps maintain this exposure and keep the lung retracted. The auricular appendage is used as the route to the mitral valve. In the event of a completely thrombosed appendage, clot must be incised or the superior pulmonary vein used as a portal of entry to the left auricle. However, the great enlargement of the left auricle reduces the exposure of the pulmonary vein and renders this approach somewhat hazardous.

After exposing the auricular appendage the surgeon inserts a purse string of heavy silk approximately 0.5 to 1.5 cm. distal to the base of the appendage (Fig. 476). The sutures should not penetrate the entire thickness of the auricular wall If the size of the appendage permits, a second opposing purse string is inserted 1 cm. distal to the first one. After carefully visualizing the adjacent coronary artery, the surgeon places a noncrushing clamp across the base of the appendage (Fig 477) An incision is made into the distal portion. If loose clot is present in the appendage,

the occluding clamp is temporarily opened to wash out any free thrombus. The incision into the appendage is enlarged and fine trabeculae are divided to permit unobstructed passage of the finger. The finger is inserted through into the chamber of the auricle as the occlusion clamp is removed and simultaneously the assistant snugs up the most distal purse string to effect complete hemostasis. The surgeon examines the mitral valve and determines the type and extent of stenosis and the location of the commissures. The anterolateral commissure lies at approximately eleven o'clock, the posteromedial commissure at five o'clock. Many commissurotomies can be satisfactorily performed by finger-fracture; and this should certainly

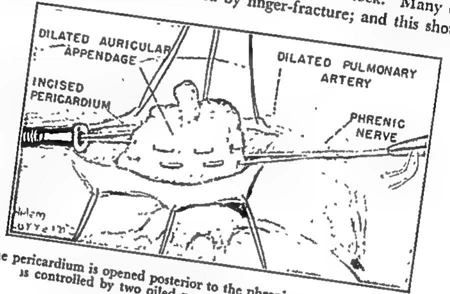

Fig. 476.—The pericardium is opened posterior to the phrenic nerve. The auricular appendage is controlled by two oiled purse-string sutures of heavy silk.

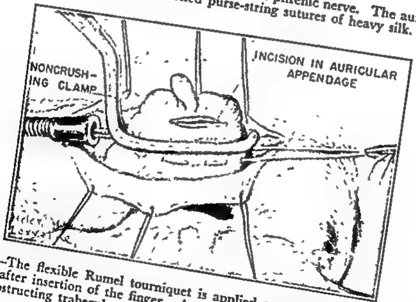

Fig. 477.—The flexible Rumel tourniquet is applied to the distal purse-string suture to prevent leakage after insertion of the finger. An appropriate clamp controls the appendage as it is incised Obstructing trabeculae are cut before insertion of the finger.

be attempted first (Fig. 478). In some instances instrumental incision will be required. A rigid internal rim around the central orifice of an otherwise flexible valve may defy accurate, safe finger-fracture. A variety of instruments have been devised for this purpose, including various guillotine knives (Fig. 479). The two-glove technic is employed to fasten the knives to the index finger. Most of these instruments have the disadvantage of not permitting simultaneous palpation of the commissures. If an instrument is used to initiate the commissurotomy, the procedure

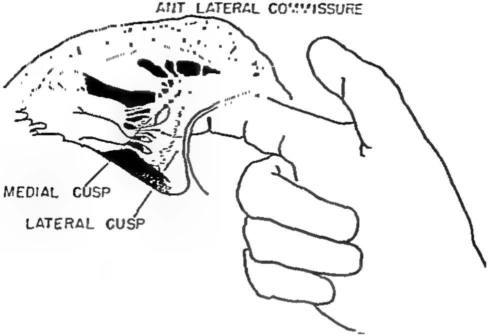

Fig. 478.—The posteromedial commissure is usually fractured first, then the anterolateral commissure.

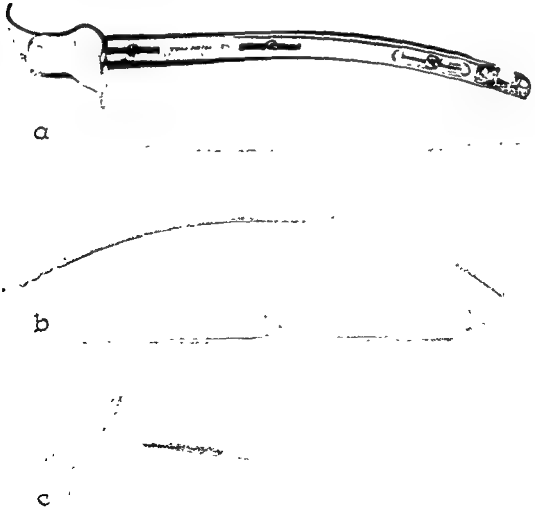

Fig. 479. *a*, Bailey guillotin 'fe

can usually be completed with the finger. In splitting the commissures great care must be exercised not to tear into the leaflets or to disrupt the chordae tendineae which act as guy wires to stabilize the leaflets. The medial commissure offers greater difficulty than does the lateral commissure. Bailey has contended that in many instances splitting of the lateral commissure only is sufficient and incurs less risk of resulting regurgitation, which should be avoided at [illegible] or major leaflet protects the [illegible] regurgitation, whereas injury [illegible] is less serious. For this reason pressure should be exerted against the minor rather than the major leaflet. During the examination and manipulation of the valve the surgeon should avoid occluding the stenotic orifice for more than a few heartbeats. After commissurotomy the surgeon determines by tactile sensation what degree, if any, of regurgitation has been incurred. After removal of the finger the auricular appendage is completely occluded by tying the purse-string sutures and oversewing the stump. The obliteration of the left auricular appendage will serve to reduce the hazards of peripheral embolization. The pericardium is closed loosely, permitting adequate drainage into the pleural space.

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CHAPTER 43

CONGENITAL ANOMALIES OF THE HEART AND GREAT VESSELS

I. A. Bigger

CLOSURE OF PATENT DUCTUS ARTERIOSUS

In 1907 Munro of Boston advocated ligation of the patent ductus, but not until thirty years later was the operation attempted. Strieder, also of Boston, performed the operation on a patient with a patent ductus complicated by bacterial endarteritis. Unfortunately the patient did not survive. In 1938 Robert Gross performed the operation successfully and the following year reported on four ductus ligations, all successful. Since that time numerous large series of operations for occlusion of the patent ductus have been reported from this country and elsewhere. In his first reports Gross suggested that bacterial endarteritis might be a contraindication to the operation, but starting in 1940 Touroff operated upon a group of patients with patent ducti and bacterial endarteritis. Touroff demonstrated that the operation could be performed without too great risk in the presence of bacterial endarteritis. He also showed that occlusion of the ductus alone controlled the infection in a considerable number.

The development of the antibiotics has made it possible to control bacterial endarteritis in the majority of patients without the aid of surgery. It is therefore now considered wise to withhold surgery until the infection has been controlled or has been shown to be resistant to antibiotic therapy, for the operation can be performed more easily and more safely after the inflammatory reaction has disappeared.

In spite of the fact that endarteritis can now be controlled by nonsurgical means, it is the consensus of those familiar with the problem that proved patent ducti in children and young adults should be operated upon even in the absence of definite symptoms. This conclusion seems to be valid, for the operation for occlusion of the ductus can be performed by surgeons well trained in this field, with small risk; the mortality in uncomplicated cases should not exceed 1 or 2 per cent. Although it is not possible to accurately estimate the risk associated with persistent patency of the ductus, it seems certain it is several times as great as the risk from properly executed surgical occlusion of the ductus. Persistent cyanosis is the most definite contraindication to closure of the patent ductus. In the presence of cyanosis, the ductus may be acting in a corrective or compensatory capacity and should therefore not be closed The optimum age for this operation probably is four to six years.

While there is rather general agreement that the ductus should be occluded, there is considerable difference of opinion among surgeons as to the best approach to the region of the ductus, and the most satisfactory method of occluding it. Gross

has from the beginning used the anterior or anterolateral submammary incision with entrance to the chest through the left third intercostal space. The incision is carried from the sternum to the posterior axillary line (Fig 480), the left side being elevated on a sandbag to make this feasible. The anterior serratus fibers are cut across to near the long thoracic nerve, and the anterolateral border of the latissimus dorsi is divided. The intercostal muscles are separated from the upper border of the fourth rib, well back to the region of the rib angle. One or two cartilages, usually the third and second, are divided at the sternum for wider exposure. This approach gives an entirely adequate exposure in children and in most adult males. In adult females, especially those with large breasts, the anterolateral approach is less satisfactory.

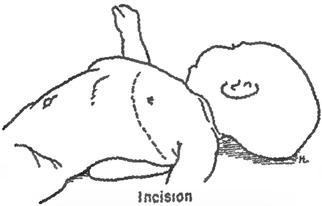

Fig. 480.—Incision used in operation for closure of patent ductus arteriosus. Note that the incision extends to the posterior axillary line.

Potts, Jones, Crafoord, and others prefer the posterolateral approach, through a curved incision starting near the spine at the level of the fourth interspace or fifth rib, passing laterally below the angle of the left scapula and then forward to the mid- or anterior axillary line. In children, entrance to the thorax is usually through the fourth intercostal space. In adults, with more rigid structures, subperiosteal resection of either the fourth or fifth rib is advisable. The decision as to which approach to use depends to some extent on the individual preference of the surgeon. The chief advantages of the anterolateral approach are: that the patient is in the dorsal recumbent position, which, as shown by Beecher, is desirable, especially when prolonged anesthesia is anticipated; also, that, except in large-breasted females, the anterolateral incision is less time-consuming and requires less hemostasis. Although the posterolateral incision has certain disadvantages which have been indicated, it does give a more complete exposure of the ductus area and, in case of serious hemorrhage, control can be more easily and more certainly accomplished through that approach. With this in mind, the method of closure of the ductus to be used should have a part in the decision regarding the approach. Since there would seem to be a greater chance of serious hemorrhage when the ductus is divided and sutured, the decision to divide and suture the ductus would influence one to use a posterolateral incision. This is in spite of Gross' remarkable record of several hundred patent ducti closed by division and suture without serious hemorrhage.

The decision as to whether to occlude the ductus by the application of multiple ligatures or by division and suture should be arrived at on the basis of the surgeon's experience and to some extent his preference, as well as on the age and build of

the patient, the character of the adjoining vessels, and the length and size of the ductus. There is little doubt that excellent results may be obtained, either by the use of multiple ligatures, properly applied, or by division and suture. The results reported by Scott, from Blalock's service, is confirmatory evidence of the above statement; in 161 cases done by the suture ligation technic there has been no case of recanalization. In 180 consecutive cases there was one recanalization, and this was in a case with active *Streptococcus viridans* endarteritis where only two braided silk ligatures were applied.

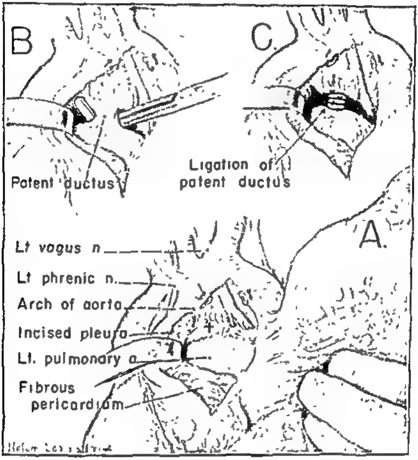

Fig. 481.—Closure of patent ductus arteriosus. *A*, The mediastinal pleura has been incised. *B*, The pericardium has been completely separated from the ductus. *C*, The series of ligatures is applied so as to occlude the entire length of the ductus Careful dissection usually reveals that the entire ductus is considerably longer than it first appears.

The ductus is readily identified by palpation in the area between the terminal portion of the primary pulmonary artery and the descending limb of the aortic arch, a short distance distal to the origin of the left subclavian artery. As an additional aid one may expose the vagus nerve and follow its recurrent laryngeal branch to the site where it turns back underneath the arch, at the junction of the ductus with the aorta. The mediastinal pleura is incised longitudinally about 1 cm. posterior to the phrenic nerve, centering the incision over the ductus (Fig 481, *A*). Before incising the pleura, it is advisable to inject approximately 10 c.c of 2 per cent procaine solution above the ductus level, infiltrating subpleurally around the phrenic and vagus nerves. This puts the left diaphragm temporarily at rest and may aid in preventing vago-vagal reflex disturbances. To completely abolish such reflexes,

however, one would have to inject both vagus nerves and infiltrate the entire area adjacent to the arch of the aorta. The mediastinal pleura is elevated on each side of the incision; the highest intercostal vein is divided between ligatures, and all superficially placed lymph nodes overlying the ductus area are removed. Great care should be exercised at this stage to control bleeding immediately since infiltration of the tissues by blood will add to the difficulty of identifying the recurrent nerve, which should be exposed early in the dissection and kept in the field of vision to avoid injury to it. The pericardium usually extends over the ductus to the wall of the aorta. This lappet of pericardium must be dissected completely off the ductus, and this should be accomplished without entering the pericardial sac, otherwise the pericardial fluid will foam over the field of dissection and interfere with vision. Should the pericardium be entered, it is better to enlarge the opening sufficiently to permit the introduction of a suction tube with fenestrated sheath to remove the excess fluid. The pericardium is most easily separated from the ductus in the subadventitial plane. Small, blunt-pointed, curved dissecting scissors are invaluable for such dissection. After completely freeing the anterolateral surface of the ductus, a curved, blunt-pointed cystic duct clamp is very carefully worked around the posteromedial surface of the ductus near the aortic end. This is often the most tedious and no doubt the most treacherous part of the operation, for a rather dense fascial plane extends from this surface of the ductus to the left main bronchus and to the adjacent great vessels. However, if the dissection is in the proper plane, there should be no great difficulty. Since the ductus is a thin-walled structure, the point of the clamp must not be directed into the vessel wall, and the index finger of the left hand should be kept continuously against the tip of the clamp to insure against that error. This part of the dissection should never be done by alternately opening and closing the clamp but by slowly moving the closed tip through a short arc, from side to side, at the same time applying gentle pressure. When the tip of the clamp emerges from the posteromedial side of the ductus (Fig. 481, *B*), the blades are gently opened and a No. 3 catgut ligature is grasped and drawn around the ductus for traction At this stage the ductus should be occluded for two or three minutes, during which period the color, blood pressure, pulse rate, and pulse volume are carefully checked. The traction ligature is used to gain better exposure while the freeing up of the posteromedial surface is completed. The greater part of this dissection must be done with a sharp instrument, under direct vision. The ductus must be completely separated from the adjacent structures including the pericardium, regardless of the method of occlusion one expects to use. If multiple ligatures are to be used, it is helpful to tie the heavy catgut ligature near the aortic end of the ductus. The catgut is so used because one can judge the pressure actually applied to the vessel wall more accurately when using catgut than when using heavy braided silk since the catgut produces less drag, or friction, than does the heavy silk. Slight traction is then applied to the catgut in the direction of the pulmonary artery and one or two heavy braided silk ligatures are tied down snugly on the aortic end of the ductus, leaving a narrow segment of vessel wall showing between the adjacent ligatures (Fig. 481, *C*). At least two heavy silk ligatures also are tied on the pulmonary artery side of the catgut ligature, if possible leaving a little space between each ligature and those adjacent to it. This technic rarely will be followed by recanalization.

Blalock uses a purse-string suture ligature of somewhat lighter grade silk at each end of the ductus and narrow tape ties or mattress sutures between.

When the ligatures have been securely tied, the lappet of pericardium is fully sutured to the adventitia of the aorta, so as to completely cover the d Fine four 0 or five 0 black silk on fine French needles is used for these sutures. mediastinal pleura also is carefully approximated with fine silk sutures. The silk ligatures are carefully covered by pericardium and pleura to protect them contact with the lung, on the basis of Jones' experience in two cases in whic heavy ligatures were not covered. These patients developed fistulas betwee aorta and bronchi. Jones was able to close the fistula in one, and the oth covered spontaneously.

Gross, Jones, Potts, Wangensteen, and many others more or less routine vide patent ducti and suture the ends. Gross applies four specially prepared h stats and severs the ductus between the two inside clamps. These two clam then removed and the pulmonary artery end of the ductus is closed by insert continuous over-and-over suture through that portion projecting beyond the c starting at the top and then returning from below upward and tying at th Fine silk on atraumatic needles is used and the sutures are closely spaced, sc there is rarely appreciable seepage when the clamp is removed. The aortic e the ductus is closed in the same fashion.

Potts uses much the same technic but employs two of his specially desi ingenious clamps. The clamps are so placed as to leave adequate width for di and suture.

When the anterior approach is used, the divided cartilages are sutured t sternum, preferably with fine stainless steel wire, and the third and fourth cart are fixed together with pericostal sutures of a heavy catgut. Special care mu taken to avoid including the nerve when passing the suture around the border of a cartilage or rib

The posterolateral incision is closed by carefully placed pericostal sutur cluding the fourth and fifth ribs. The muscles, fascia, and skin are approxin in anatomical layers.

OPERATIVE CORRECTION OF COARCTATION OF AORTA

The adult type of coarctation of the aorta usually occurs as a narrow stri of the distal portion of the aortic arch located a short distance below the orig the left subclavian artery near the aortic end of the obliterated ductus arteri The degree of stricture may vary from moderate narrowing to complete obstru of the aortic lumen The clinical effects depend to a large extent upon the de of stricture. In moderate strictures, there may be only slight differences in b pressure between the upper and lower extremities, and the individual may le normal life for a normal span. On the other hand, individuals with near or plete obstruction of the aorta usually have marked hypertension in the uppe tremities and hypotension in the lower extremities Frequently, there is no der strable pulse in the lower portion of the body. Interestingly enough, the symp and complications of coarctation are mainly the result of hypertension in the u portion of the body rather than hypotension below Even renal function appar is not seriously impaired by the low pressure in the renal arteries The most im tant causes of death in individuals with marked stricture of the aorta and assoc severe hypertension are cardiac failure and cerebral vascular accidents. Suba

bacterial endarteritis and rupture of aortic aneurisms also take a certain toll. It is difficult to estimate the effect of coarctation of the aorta on longevity, for, as stated, many individuals with coarctation are not particularly handicapped by it and some live to a ripe old age. However, the great majority of individuals with coarctation who show marked elevation of blood pressure in the upper portion of the body have a shorter than average life span. It is evident that one must assume a somewhat different attitude toward operations for the relief of coarctation of the aorta and operations for closure of the patent ductus arteriosus. This is the case not only because of the greater variation in the prognosis of individuals with coarctation, but also because the operation for the correction of coartation is a more serious undertaking than is closure of the patent ductus. Under present conditions it is reasonable to assume that operation for coarctation should be recommended only when there is definite associated hypertension in the upper extremities and hypotension in the lower extremities. The optimum age for operation has not been certainly established, but since the experiments of Brooks, Hurwitt, and others seem to show that anastomotic rings, the result of division and suture of the aorta in puppies, increase in diameter more or less in proportion to general bodily growth, it is unnecessary to delay until adult stature has been attained. Also it is quite important that the hypertension be relieved before irreversible vascular changes have occurred. Furthermore, the operation is less difficult when done in childhood. With these and other considerations in mind, the optimum age would seem to be somewhere between six and twelve years.

The first operation recommended for coarctation was based on experimental work alone. A description of the procedure and the experimental evidence that such an undertaking was feasible were presented by Blalock before the Southern Surgical Association in December, 1943. The operation suggested was the end-to-side anastomosis of the left subclavian artery to the aorta distal to the stricture. One year later, 1944, Crafoord of Stockholm performed the first operation for coarctation in a human being, and the following year, 1945, Gross independently used a technic almost identical with that used by Crafoord.

The operative procedure used by Crafoord and by Gross is superior to the operation proposed by Blalock and should be used when it is feasible to do so (Fig. 482). The essential part of the operation is resection of the strictured area and end-to-end anastomosis of the proximal and distal aortic segments (Fig. 483, *A*). When this cannot be done because of the length of the strictured area, or in the presence of other conditions which make it impossible to bring the aortic segments together for end-to-end suture, the left subclavian artery may be used for end-to-side or end-to-end suture to the distal aortic segment (Fig. 483, *B*). The chief disadvantage is the loss of the large collateral flow through the dilated subclavian artery. At times, because of the length of the stricture, or because of an aneurism in the proximal portion of the distal aortic segment, even the additional length available through use of the subclavian is inadequate and one must consider the advisability of using a vascular graft, either venous or arterial. If it is possible to obtain a fresh autogenous vein graft of suitable size, that would seem the better choice, since suitable autogenous arterial grafts are not available. Johnson seems to have demonstrated that fresh autogenous vein grafts give satisfactory results. Gross, on the other hand, has shown experimentally and clinically that properly preserved homografts of arteries will survive and serve to transport blood. The entire problem con-

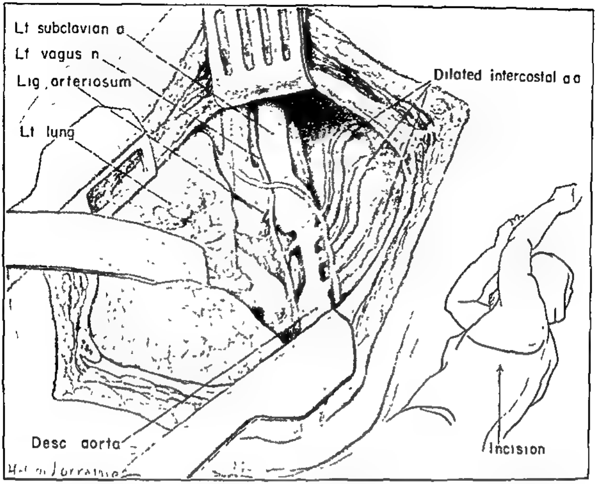

Fig 482.—Operation for correction of coarctation of the aorta. The area of stricture is shown with the dilated intercostal arteries. The position of the patient and the incision are shown in the inset

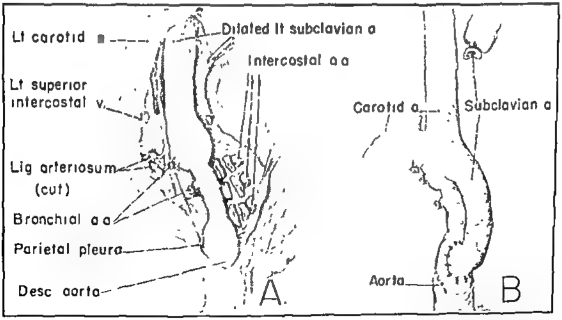

Fig. 483—Operation for correction of coarctation of the aorta. *A*, The intercostals have been ligated and divided and the area of stricture has been separated from the surrounding tissue so that an end-to-end anastomosis of the aorta can be made *B*, Alternate procedure with end-to-side anastomosis when stricture is elongated

cerning vascular grafts requires further study, especially in regard to long-term results. Until more is known of their ultimate fate, their use should be restricted to the large medical centers where carefully controlled investigation may be carried on.

The technic for resection of the stricture and anastomosis of the aortic segments is reasonably well standardized, including the approach, which is through a posterolateral incision. The patient is placed on the right side, well supported so as to avoid change of position during the operation. The left arm is elevated above the head so as to displace the scapula upward. The incision extends from near the spine along the fourth or fifth rib, below the angle of the left scapula to the anterior axillary line or beyond. Practically the entire fourth or fifth rib is resected subperiosteally so as to gain a wide exposure. The thoracic wall incision usually is time-consuming and tedious, especially in adults because of the extreme vascularity of the area. An excellent exposure of the arch and upper portion of the descending aorta is obtained by the use of a good rib-spreading retractor. The site of coarctation is easily identified, but the degree of stricture is usually not apparent until the pleura has been elevated, and, indeed, one may not be able accurately to estimate the narrowness of the stricture until the adventitia is removed from that portion of the vessel. It is necessary that the adventitia be completely dissected from the vessel wall at the level of anastomosis. Unless this is done, the clamps used for control of bleeding and approximation of the segments for suture will not hold satisfactorily. Special care must be taken to avoid injury to the intercostal arteries, especially those on the right, for they are extremely fragile and may be difficult to ligate. Also they are important collateral channels.

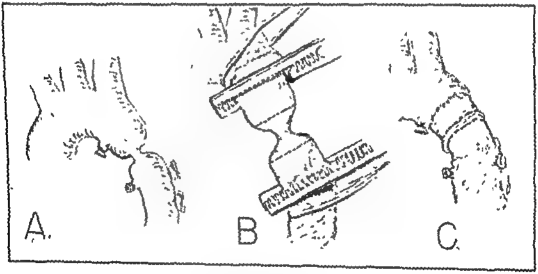

Fig 484—*Technic of resection of stricture and end-to-end suture of the aortic segments, the procedure of choice.*

Provision must be made so that there will be adequate projection of both segments of aorta beyond the approximating clamps, otherwise the placing of sutures will be much more difficult. It usually is more difficult to obtain sufficient cuff of the proximal segment because of the nearness of the stricture to the origin of the left subclavian artery. Blalock has solved this problem admirably, by using a modified Smith-Potts clamp, so placed that it permits some blood to pass from the proximal aorta out through the subclavian but prevents blood from escaping through the

segment of aorta beyond the subclavian. The large-sized Potts fine-toothed clamp serves well for the distal segment and for the proximal segment when there is adequate length distal to the subclavian. Enough of the strictured area is excised to give an adequate lumen. The segments are approximated by continuous, everting mattress sutures of five 0 silk, first placing the posterior sutures, then the anterior (Fig. 484). The ends of the two sutures are then tied, one to the other. When the continuous suture has been completed and the ends have been tied, the clamps are removed. Gross feels that it is very important to release the clamps slowly, since he lost one of his early cases, presumably because the clamps were released rapidly. If there is leakage at any site, a few interrupted sutures may be used to control it. These sutures should be superficially placed so that they will not present within the lumen. The exposed portion of the intima should be kept moistened with normal saline during the period required for suturing.

The pleura is carefully sutured over the site of anastomosis, and the chest wall incision is approximated in anatomic layers, starting with approximating sutures in the rib bed which include the pleura and periosteum. Because of the vascularity of the wound an intercostal catheter may be inserted through a puncture wound. The catheter should be placed in contact with the upper border of a rib so as to avoid pressure on the intercostal nerve. Even with care the blood loss in these operations is considerable and should be replaced in so far as possible as it is lost. Antibiotics, especially penicillin, should be used locally and parenterally.

While the everting mattress suture seems preferable, a carefully placed, continuous, over-and-over suture, so located as to bring the various coats in anatomic apposition and including a narrow segment of intima, is satisfactory. Crafoord uses the over-and-over suture but does not include the intima. Nonabsorbable sutures are generally used, but there are some arguments in favor of using absorbable sutures when operating upon children.

OPERATIONS FOR THE RELIEF OF PRESSURE UPON THE ESOPHAGUS AND/OR TRACHEA, THE RESULT OF CERTAIN ANOMALIES OF THE AORTIC ARCH

Gross, Potts, Clagett, and a number of other surgeons have reported the results of operations performed for the relief of pressure upon the esophagus and/or trachea by certain anomalies of the aortic arch, and many possibilities exist for these anomalies to cause pressure on the trachea and esophagus. In the majority of cases, however, such anomalies give rise to no symptoms.

A number of operations have been reported for the relief of dysphagia and respiratory distress produced by double aortic arch. Division of some portion of the arch relieves the compression of the trachea and esophagus to a large degree. In the majority of such cases, the anterior arch is the smaller and is, therefore, the one usually divided. When the anterior arch is to be divided, the anterolateral approach gives an excellent exposure. Unfortunately, it is not possible to be certain preoperatively which portion of the double arch is the smaller. With this in mind and in view of the experience reported by Potts, it may be advisable to use the posterolateral approach, since both the anterior and posterior divisions of the arch can be well visualized when that approach is used. The site of division should be

determined on the basis of accessibility, length of vessel available for division between ligatures, and, especially, the effect on blood flow through the important branches of the arch.

Gross has reported dysphagia produced by pressure on the posterior wall of the esophagus by a right subclavian artery which arose from the left side of the aortic arch. The euphonious term, dysphagia lusoria, is used to describe this condition. The approach here was through an anterior incision which gave an adequate exposure. The artery was divided between ligatures near its origin from the aorta. A posterolateral incision is probably more certain of giving a satisfactory exposure in operations for most aortic arch anomalies.

SURGERY OF PULMONARY STENOSIS

Lewis H. Bosher, Jr.

The major physiologic disturbances associated with congenital pulmonary stenosis consist of a marked reduction in pulmonary blood flow and usually a right to left intracardiac shunt, through which a large quantity of venous blood is released into the systemic circulation. The degree of cyanosis depends on the size of the right to left shunt, the caliber of the pulmonary stenosis, and the concentration of hemoglobin, which is almost always elevated above normal. The exercise intolerance of patients with pulmonic stenosis may be extreme.

The pathologic syndrome designated as tetralogy of Fallot is characterized by pulmonary stenosis, a high interventricular septal defect, dextroposition of the aorta with overriding of the septal defect, and hypertrophy of the right ventricle. Sixty per cent of patients in the cyanotic group of congenital heart disease fall into this category. The stenosis in tetralogy of Fallot usually involves the subvalvular or infundibular portion of the right ventricle. However, in some instances (perhaps 25 per cent) the stenosis is located at the level of the pulmonary valve.

Somewhat less common than tetralogy of Fallot is "pure" pulmonary stenosis in which the interventricular septum is intact and the aorta is not dextroposed. A patent foramen ovale or interauricular septal defect is present in more than 70 per cent of cases. In "pure" pulmonary stenosis the obstruction is almost always found at the level of the valve. As in tetralogy of Fallot, the amount of right to left shunt is closely related to the degree of pulmonary stenosis and the resulting high pressure in the right heart.

Careful diagnostic studies, including arterial oxygen saturation and oxygen consumption tests, fluoroscopy, electrocardiography, angiocardiography, and cardiac catheterization, are required to arrive at a precise diagnosis. By these means one confirms the suspicion of reduced pulmonary blood flow and establishes the presence or absence of an interventricular septal defect and overriding aorta. If the level of the stenosis can be determined preoperatively by these methods, the surgeon may be aided in the selection of the operative approach and the most suitable procedure.

A. Systemic to Pulmonary Artery Shunt Procedures

The operations developed by Blalock and by Potts increase the pulmonary blood flow and improve the arterial oxygen saturation by shunting incompletely oxygenated blood from the systemic circulation into the pulmonary circuit. The

results have been spectacular in most patients with tetralogy of Fallot. In certain other rarer forms of congenital cyanotic heart disease, such as malfunctioning right ventricle with a large interatrial septal defect and in some cases of truncus arteriosus, considerable improvement has been noted. Good results have not been obtained in patients with "pure" pulmonary stenosis, either with or without an interatrial septal defect, or in transposition of the great vessels. The construction of a shunt would not seem advisable for Eisenmenger's complex, where the pulmonary pressure is already excessively high.

Surgical treatment should not be undertaken on children under two years of age unless survival without treatment appears extremely unlikely. The mortality in this age group exceeds 30 per cent, whereas a mortality under 10 per cent may be anticipated in patients between the ages of three and twelve years. Likewise, patients in the older age groups, i.e., over twenty years, represent extreme surgical risks. Accurate diagnosis in the newborn and young infant may be extremely difficult. Furthermore, the development of certain compensatory phenomena such as polycythemia may permit the patient to withstand the operative procedure better at a later date. The technical problems are of far greater magnitude in tiny infants, and vessels of adequate size may not be available for anastomosis. Growth of the anastomotic lumen is restricted by nonabsorbable, continuous sutures, and consequently a shunt which seemed adequate for an infant may prove insufficient in later childhood. This constitutes an added reason for delaying the operative procedure beyond infancy, if possible. The use of absorbable suture material may partially eliminate this restriction on the growth of the anastomotic lumen.

In the preoperative preparation the maintenance of adequate hydration should be stressed to reduce the threat of cerebral and anastomotic thrombosis in the early postoperative period. These patients frequently exhibit low-grade fever, presumably due to pulmonary infection, and administration of antibiotics in the preoperative period often establishes a normal temperature level Digitalis is indicated for patients with evidence of cardiac failure. The presence of much cardiac enlargement, however, suggests an atypical type of tetralogy, "pure" pulmonary stenosis, or some other type of congenital heart disease which may respond unfavorably to a shunt procedure.

During operation the prevention of hypoxia and respiratory acidosis by adequate pulmonary ventilation offers the best assurance against bradycardia, arrhythmias, and cardiac standstill, events which have been reported frequently during surgery for cyanotic congenital heart disease. Anoxia and hypotension, even of short duration, may produce irreversible cerebral damage or thrombosis. In the case of the extremely cyanotic and desperately ill infant, Potts advises reduction of body temperature during operation to 96° F. by means of a water-cooled mattress. Blood loss, unless extreme, should be replaced by plasma, since the decrease in polycythemia reduces the chance of postoperative thrombosis Hypotension and shock also predispose to thrombosis at the anastomosis by decreasing blood flow through the shunt Prophylactic anticoagulant therapy is unnecessary and dangerous. Only in the event of a cerebral thrombosis or thrombosis at the anastomotic site should anticoagulant therapy be instituted.

In the Blalock procedure a major branch of the aortic arch is utilized; in the Potts operation the aorta itself is anastomosed to the adjacent pulmonary artery.

In both procedures an adequate differential in pressure between the systemic and pulmonary circuits must exist to encourage blood flow through the shunt and thus maintain patency of the anastomotic lumen. This principle emphasizes the importance of maintaining an adequate systemic pressure during the operative and postoperative periods. Whereas the size of the shunt in the Blalock procedure is controlled by the diameter of the systemic vessel employed, usually the subclavian, in the Potts procedure the size of the anastomotic lumen can be regulated by the surgeon. An excessively large shunt may precipitate pulmonary edema.

A clear understanding of certain anatomic features will assist the surgeon in appraising the various shunt procedures. A variety of vascular anomalies may be encountered in patients with congenital heart disease. Approximately 20 per cent of all patients with tetralogy of Fallot have a right aortic arch. In such instances the subclavian artery arising from the innominate artery is most accessible through the left thorax in contrast to the normal situation. Atresia of one or both pulmonary arteries is found in some of the more desperately ill cases. Angiocardiography is helpful in establishing the existence of both pulmonary arteries and in guiding the operative approach. A patient will rarely survive total occlusion of the only existing pulmonary artery during the performance of a shunt. In such a situation it has been advised that the operative approach be made on the side of the atretic or small pulmonary artery. In the event that a satisfactory shunt cannot be constructed on that side, a partial occlusion of the pulmonary artery or total occlusion of one of its branches on the contralateral side may be attempted at a subsequent procedure. However, the chances for success would seem to be greater if this latter procedure were performed initially.

The level of the aortic arch in the chest varies considerably as does the resulting gap between the arch and the pulmonary artery. In general, this distance widens with increasing age and height. The left pulmonary artery lies at a higher level in the chest than does the right pulmonary artery, and a greater length of the former vessel may be isolated for anastomosis. The superior vena cava must be well mobilized to expose the main right pulmonary artery adequately. Failure to do this may cause the surgeon to mistake the superior division of the pulmonary artery for the main right pulmonary artery. The subclavian artery from the innominate vessel provides a better angle with the parent vessel after an anastomosis with the pulmonary artery than does the subclavian which arises directly from the aorta and has to be turned back across the arch. However, the subclavian of the innominate is somewhat shorter than is the subclavian which arises directly from the aorta. When the approach is made on the side of the innominate artery, a more extensive mediastinal dissection will be required to mobilize the desired subclavian vessel The use of the carotid or innominate arteries cannot be justified because of the high incidence of cerebral complications following division of these vessels. If a retroesophageal subclavian artery is encountered, this vessel should be displaced anterior to the tracheobronchial tree before carrying out the anastomosis in order to avoid creating a vascular ring around the trachea and esophagus.

The age and size of the patient introduce other considerations. In the very young infant a systemic vessel of satisfactory diameter other than the aorta may not be available. In the presence of a very small pulmonary artery an end-to-end anastomosis between the subclavian and the distal end of the pulmonary artery will

prove more satisfactory than either the end-to-side shunt or the aorta-to-pulmonary anastomosis. The end-to-end anastomosis is also frequently helpful in situations where a wide gap must be bridged.

In planning the operative procedure the surgeon should consider the age and height of the patient, the presence and size of the pulmonary arteries, and the level and location of the aortic arch. In the original operation described by Blalock, a branch of the aortic arch, usually the subclavian arising from the innominate artery, was anastomosed end to side to the nearby pulmonary artery. Modifications of this procedure have been suggested not only by Blalock but by other surgeons to meet a variety of circumstances. In general, Blalock has expressed preference for the utilization of the subclavian artery arising from the innominate vessel, whether this be on the right or left side, because of the more favorable angle thus formed. However, in patients over thirteen years of age or over five feet in height, the anastomosis may be difficult or impossible to complete on the right side, and in these individuals Blalock advises an approach through the left thorax. Almost all surgeons agree that, when the aorta arches to the right, an approach should be made through the left chest, since the subclavian artery arising from the innominate vessel is then easily mobilized for anastomosis to the left pulmonary artery and this anastomosis can be accomplished satisfactorily even in the older patients because of the high position of the left pulmonary artery.

Many surgeons prefer an approach from the left in all instances, except in cases of dextrocardia with a right arch. With the aorta on the left, either a Blalock or a Potts procedure can be selected. In the event pulmonary valvulotomy is being considered instead of a shunt, a left-sided approach is mandatory. Furthermore, it would seem advisable for the surgeon routinely to open the pericardium and examine the pulmonary outflow tract. In this way he may familiarize himself with the external appearance of the heart as an aid in diagnosing the level of the pulmonary stenosis and in selecting the most appropriate procedure.

The Blalock procedure as performed on the left side in the presence of a right aortic arch will be described.

The left pleural space is entered either through the second interspace anteriorly or through the fourth interspace or bed of the fourth rib in the posterolateral approach. In comparison with the anterior approach, the posterolateral incision provides better exposure and when employed through the bed of the rib permits more adequate hemostasis but is perhaps less desirable in the extremely poor-risk patient. In either instance expert anesthesia is required and the surgeon must allow adequate ventilation of the lungs at all times and complete reinflation frequently. The avoidance of even moderate degrees of hypoxia and hypercapnia is important in reducing to a minimum the incidence of cardiac arrest and cerebral complications.

After opening the pleural space the surgeon incises the mediastinal pleura at the root of the lung between the vagus nerve and the phrenic nerve. The vagus nerve at the apex of the chest is infiltrated with 1 per cent procaine to reduce vagal reflexes resulting from hilar traction and stimulation It is partially mobilized to prevent injury during subsequent dissection. The proper plane is entered about the pulmonary artery and this vessel is dissected out to determine its suitability for anastomosis Enlarged collateral bronchial arteries in the hilar region may cause troublesome bleeding and require ligation. The pulmonary artery is freed of all loose adventitia but should not be denuded too closely. It is advisable to

dissect out the first branches of the pulmonary artery to provide adequate length for occlusion during the anastomosis. It is permissible to incise the pericardium if sufficient length cannot otherwise be obtained. The left subclavian artery is identified at the apex of the chest, and it and the innominate artery are dissected out of the mediastinum. Mobilization of the left carotid artery well into the neck assists in providing sufficient length of subclavian for completion of the anastomosis without tension. The surgeon carefully avoids injury to the recurrent laryngeal nerve as it loops around the subclavian artery in the region of the obliterated ductus, which is usually found on the left even in the presence of a right arch (Fig. 485).

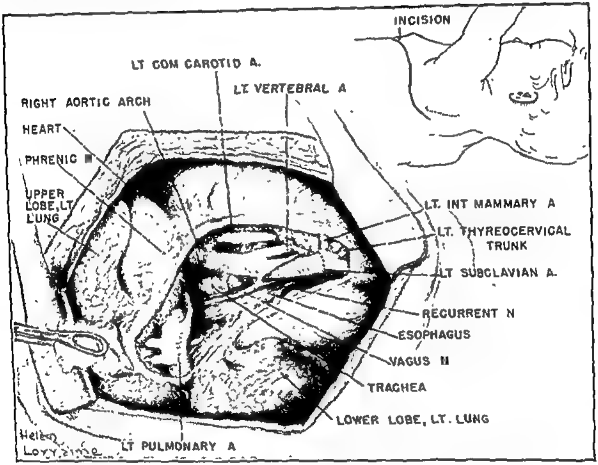

Fig 485.—The pleural space is entered through the bed of the left fourth rib. A right aortic arch is present. The left subclavian and carotid arteries arise directly from the arch (the innominate trunk is absent), and the vertebral artery takes origin more proximally than usual. Ligation of the vertebral artery is not required in this case. The branches and continuation of the subclavian artery are ligated individually. The recurrent nerve must be avoided during dissection of the subclavian artery.

Because of the frequent anomalies encountered in the major branches of the arch, the surgeon should temporarily occlude the vessel selected for anastomosis and instruct the anesthetist to check the corresponding pulse. This precaution will prevent inadvertent division of the carotid artery.

After the surgeon has satisfied himself that a successful anastomosis may be achieved, he ligates individually, in order to gain maximum length, the vertebral artery, the internal mammary, and the continuation of the subclavian artery. Although a ligation proximal to these branches would undoubtedly interfere less with the collateral circulation to the arm, serious vascular insufficiency has rarely resulted. Not infrequently the vertebral artery arises somewhat more proximally

on the subclavian, in which case it is divided and its point of origin is included the segment of subclavian artery to be turned down for anastomosis. The clavian artery is occluded with a bulldog clamp and transected just proximal divided branches. After the vessel has been withdrawn from the loop of the re rent laryngeal nerve, the bulldog clamp is replaced with a toothed Potts d clamp for more satisfactory control during the actual anastomosis. The lum the vessel is irrigated with saline solution and loose adventitia is stripped its tip. Immediately before occlusion of the pulmonary artery, the patient is

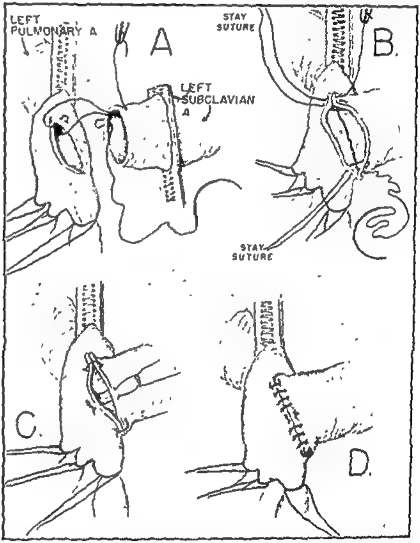

Fig 486.—After transection of the subclavian artery, the pulmonary artery is occlu first distally and then proximally An oblique incision is made into the pulmonary artery. The posterior continuous everting suture starts and ends on the subclavian artery. This ro pulled snug only after all stitches are inserted *B*, Interrupted mattress stitches are place either angle and the posterior suture is anchored to these. *C* and *D*, The anterior ro completed with interrupted mattress and single stitches

oxygenated by the anesthetist, atropine is administered intravenously if there been any tendency toward bradycardia, and the vagus nerve is again injected w procaine. The pulmonary artery and its first branches are then occluded dist with bulldog clamps or with well-oiled medium-weight silk sutures passed tw around each vessel. Various devices have been used for proximal occlusion of pulmonary artery. These include the special Blalock vertical clamp, some form

heavy ligature either twisted or tied down, or a Potts ductus clamp, which occludes well if the wall of the pulmonary artery is not excessively thin. After occluding the pulmonary artery first distally and then proximally, the surgeon may safely incise the superior wall of the distended segment with a bayonet-shaped scalpel blade. The incision should not be made too close to the proximal pulmonary artery clamp. With angled scissors the opening is enlarged to provide a lumen approximately equal in size to that of the subclavian artery. Exposure for suturing at the medial angle will be improved if the incision into the pulmonary artery is made obliquely with the medial end inclined anteriorly. Sutures of five 0 arterial silk, well oiled, are used for the anastomosis. A continuous everting suture is placed in the posterior wall and is pulled snug only after the entire row has been set (Fig. 486, *A*).

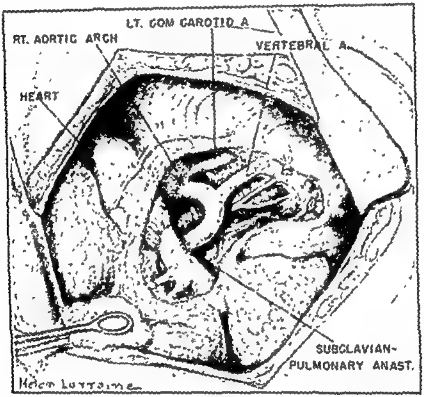

Fig. 487.—The completed anastomosis is shown following release of clamps and occluding ligatures.

Hemostatic closure of the angles is obtained by interrupted mattress sutures to which the posterior continuous suture is anchored (Fig. 486, *B*). Special care should be exercised to avoid pursing the posterior wall as the continuous suture is tied to the interrupted sutures. Because of the restricting effect of continuous silk sutures on the growth of the anastomotic lumen, interrupted sutures are employed in the anterior wall unless the condition of the patient is unsatisfactory and speed seems essential (Fig. 486, *C* and *D*). If a continuous suture is inserted anteriorly, either the over-and-over or everting type will prove satisfactory. However, in very small vessels the continuous everting suture is preferred to the continuous over-and-over suture, which leaves a considerable amount of silk within the lumen. After the anastomosis has been completed, the clamps or occluding ligatures are withdrawn from the pulmonary vessel, first from the distal end, then from the proximal end, and lastly and slowly from the subclavian artery (Fig. 487). A continuous strong

thrill indicates a satisfactory blood flow through the site of the anastomosis. Bleeding from the suture line occurs momentarily but soon ceases and may be easily controlled with a freshly excised piece of muscle. Infrequently, an additional interrupted suture will be required. Replacement of clamps is to be avoided, if possible, because of the hazard of thrombosis. If the anastomosis is completed successfully, reinflation of the lung further reduces tension on the suture line. The mediastinal pleura is left open to permit escape of blood and fluid into the pleural space, which in turn is drained with an intercostal tube.

The Blalock procedure as described may be utilized on the right side in the presence of a left aortic arch. The disadvantages of this approach have been enumerated. To provide adequate exposure the azygos vein is divided and the superior cava is mobilized well anteriorly away from the pulmonary artery Dissection of the innominate and subclavian arteries from the mediastinum is somewhat tedious. The anastomosis will be accomplished less easily on the right side because of the wider gap to be bridged.

Many surgeons prefer to use the left subclavian artery even in the presence of a left aortic arch because of the ease with which this vessel may be mobilized and the anastomosis completed. However, a distinct kinking in the subclavian artery may result as it is turned back across the aortic arch, thus limiting blood flow through the anastomosis. This reduction in flow may be sufficient to cause thrombosis in the case of a small subclavian artery. This complication is usually avoided, and undoubtedly elongation of the vessel subsequently occurs and relieves the obstruction. To reduce the kinking the anastomosis should be made somewhat laterally on the pulmonary artery. In the presence of serious kinking, Holman employs proximal division of the pulmonary artery after completing the anastomosis, a maneuver which elevates the distal segment and reduces angulation. An end-to-end anastomosis between the subclavian artery and the distal divided pulmonary artery accomplishes the same result but should not be attempted if the discrepancy in diameter between the two vessels exceeds three to one. Good results are obtained by these technics even though systemic blood is shunted to only one lung.

The Potts operation is especially useful in tiny infants when the subclavian artery is extremely small or in any patient when the wide gap between the subclavian and pulmonary arteries prevents anastomosis. It may not prove as satisfactory as an end-to-end anastomosis between the subclavian artery and pulmonary artery when the latter is unusually small.

Some surgeons utilize the Potts procedure almost routinely in preference to the Blalock operation when a left aortic arch is present. The possibility of sudden disastrous hemorrhage during operation is potentially greater in the case of the Potts operation because of the large size of the vessel being utilized and the impossibility of sacrificing this vessel should serious bleeding occur. There is also some danger of tension on the suture line when the pulmonary artery must be displaced appreciably for approximation with the aorta. The marked discrepancy between the thickness of the wall of the aorta and the wall of the pulmonary artery seems to have little practical importance in achieving a functioning anastomosis. The Potts operation is difficult on the right side because of the very unsatisfactory angle of the right pulmonary artery with a right aortic arch. However, in tiny infants this operation may offer the only suitable solution even when the arch is on the right. In some instances this has been satisfactorily accomplished by performing an end-

to-side anastomosis with a branch of the pulmonary artery instead of the usual side-to-side procedure with the pulmonary artery.

The Potts operation is far more easily performed through a posterolateral approach, usually through the bed of the fourth rib. The mediastinal pleura is incised and the pulmonary artery and its branches are dissected free as described for the Blalock operation. The vagus and recurrent nerves are identified and protected. The pleura is dissected back from the aorta opposite the pulmonary artery and a sufficient segment of the former is freed up by ligation of intercostal arteries to allow safe application of the special Potts-Smith clamp (Fig. 488). This dissection requires sacrifice of several collateral vessels coursing over the aorta. During dissection of the intercostal arteries care must be exercised to avoid injury to the thoracic duct. A Potts-Smith clamp properly selected as to size is applied to the aorta and the medial wall is isolated The adventitia is cleaned away. The presence of a thrill below the occluding clamp indicates persistence of aortic flow.

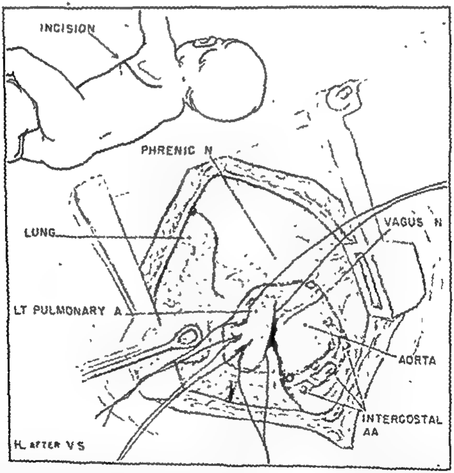

Fig 488.—The pleural space is entered through the bed of the left fourth rib. After incision of the mediastinal pleura the pulmonary artery and its branches are isolated. The aorta is freed up after division of several intercostal arteries

The first branches of the pulmonary artery are occluded by twice encircling oiled silk ligatures previously passed around the isolated vessels. The pulmonary artery proper is likewise occluded distally and then proximally by encircling ligatures which are then tied to the lower flange of the Potts clamp (Fig. 489, *A*). A distended segment of pulmonary artery is thus approximated to the isolated lip of the aorta The surgeon makes an incision 1 cm. in length exactly into the central por-

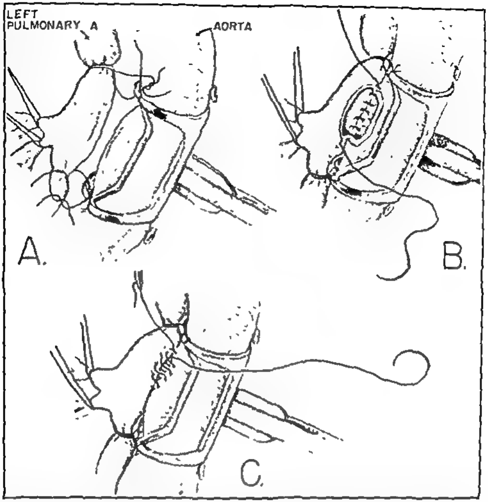

Fig. 489 —*A*, The Potts-Smith clamp is applied to the aorta and the occluded pulmonary artery is approximated to it with ligatures *B* and *C*, Incisions (0.5 cm in length) are made in each vessel. The anastomosis is accomplished with a continuous over-and-over suture

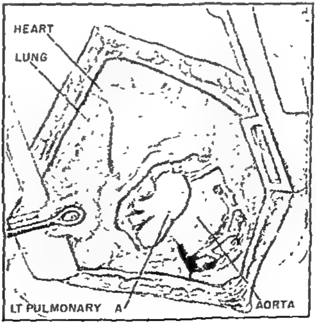

Fig. 490.—The distal ligatures are released, then the proximal ligature The completed anastomosis is shown

tion of the isolated aorta, creating two lips of equal width. A corresponding incision is made into the pulmonary artery and the lumina of the isolated segments are flushed with saline (Fig. 489, *B*). Continuous over-and-over five 0 arterial silk is employed for the anastomosis on both the posterior and anterior walls (Fig. 489, *C*). Single interrupted sutures inserted at the angles of the anastomosis serve to reduce tension on the suture line.

After completing the anastomosis, ligatures on the branches of the pulmonary artery are removed first, followed by release of the distal approximating ligature between the pulmonary artery and the aorta, then the proximal one. Finally, the Potts-Smith clamp is slowly unscrewed. (Fig. 490.)

B. Valvulotomy for "Pure" Pulmonary Stenosis

The systemic to pulmonary artery shunt has not proved satisfactory in the treatment of "pure" pulmonary stenosis. In the absence of an interventricular septal defect the shunt procedures cause a rise in the left auricular pressure, which results in a decrease in the right-to-left shunt through the interauricular septal defect. The work of the right heart is thereby increased and failure usually results

In "pure" pulmonary stenosis the obstruction is commonly found at the pulmonary valve, which is replaced by a rigid diaphragm with a small central perforation. The pulmonary artery distal to this obstruction is dilated unless there is an infundibular obstruction associated with the valvular stenosis or hypoplasia of the pulmonary vessel.

Regardless of the presence or absence of an interauricular septal defect, valvulotomy represents the only satisfactory solution to "pure" pulmonary stenosis. Not only is the pulmonary flow augmented, but the reduction in right ventricular and right auricular pressure decreases the right-to-left shunt. The operative results have been equally as spectacular as in cases of typical tetralogy of Fallot treated by the shunt procedure. The operation may be expected to restore many individuals to a nearly normal existence. In a limited number of cases of tetralogy of Fallot the stenosis is located at the valve level also. Valvulotomy offers these patients a more complete correction of the pathologic situation without the imposition of an artificially created ductus. The technical problems encountered are similar to valvulotomy for "pure" pulmonary stenosis unless an infundibular stenosis is also present.

Some pulmonary regurgitation may result from the valvulotomy, but thus far this has not constituted a serious threat probably because of the low pressure in the lesser circuit.

The approach for pulmonary valvulotomy is made through an anterior incision in the third interspace with division of the fourth costal cartilage. Once the chest has been opened the surgeon should proceed without delay, since a fall in systemic blood pressure has frequently been noted in these patients after open pneumothorax is established The pericardium is incised anterior to the phrenic nerve, thus exposing the right ventricle, the pulmonary conus, and the intrapericardial portion of the pulmonary artery. Procaine applied locally or administered intravenously may depress the myocardium and is only utilized if the heart displays evidence of irritability.

Palpation permits confirmation of the preoperative diagnosis as the surgeon feels a thrill just distal to the valve and appreciates the expulsion of a jet of blood

through the central perforation in the stenotic valve. The normally bulging sinuses of Valsalva are absent. The main pulmonary artery is dilated. The obstructing diaphragm may be palpated by inverting the wall of the pulmonary artery with the finger.

A point is selected between coronary vessels 2 to 4 cm. proximal to the pulmonary valve. Preliminary stay sutures are placed through the myocardium and a small stab wound is made through the myocardium between the stay sutures. A curved probe passed into the right ventricle locates the central perforation of the stenotic pulmonary valve. The probe is then withdrawn, a valvulotome is inserted, and the obstructing diaphragm is bivalved. The most widely used valvulotomes utilize the arrowhead principle with sharp leading edges The proper size valvulotome must be selected to avoid injury to the valve ring Adjustable valvulotomes offer the advantage of requiring only a small myocardial incision. An adjustable dilator is opened in the valve ring following the initial incision into the valve. The cutting and dilating maneuvers should be carried out quickly in order not to interfere seriously with pulmonary flow. During the intracardiac manipulations, bleeding around the instruments is easily controlled with a finger or with the stay sutures. The myocardium is closed with several interrupted sutures The effect of the valvulotomy is immediately manifested by increased tension in the pulmonary artery.

C. Resection for Infundibular Stenosis

In at least 75 per cent of patients with tetralogy of Fallot the stenosis is located in the infundibular region Removal of this obstruction constitutes a far more difficult technical problem than does the treatment of valvular stenosis by valvulotomy, as described in the preceding section. Nevertheless, Brock has attacked the problem with some measure of success

Removal of the pulmonary obstruction may be expected to improve pulmonary flow while simultaneously reducing the right to left shunt. From a physiologic standpoint this is far more desirable than the creation of an artificial ductus.

In a low infundibular stenosis, a dilated region in the pulmonary outflow tract intervenes between the obstruction and the pulmonary valve. This is called the infundibular chamber In a high infundibular stenosis no such chamber exists.

Brock utilizes a backward biting punch which is first passed through the obstructing diaphragm or narrow channel The stenotic area together with the surrounding muscle of the outflow tract is resected in one or more bites. The region of stenosis may be approached either through the wall of the chamber or through the myocardium proximal to the stenosis

A somewhat higher mortality rate must be accepted if infundibular resection is used in preference to a shunt procedure. The final technical solution of this surgical challenge will probably have to await perfection of an extracorporeal circulation

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CHAPTER 44

THE MAMMARY GLAND

Guy W. Horsley

Operations involving the mammary gland are indicated in the treatment of infection either within the breast or anterior or posterior to it, in the treatment of chronic cystic disease of the breast, and for the removal of neoplasms either benign or malignant. Plastic operations on the breast and nipple are also occasionally indicated and often will give excellent results.

Suppuration in the mammary gland requires drainage as do abscesses elsewhere To avoid injury to the larger milk ducts the incision should be made as near the periphery as possible on a line radiating from the nipple. In large single abscesses adequate dependent drainage will usually result in a rapid clearing of the infection, but it is often difficult to drain satisfactorily a breast which is the seat of multiple abscesses. If there is evidence of gross infection of the central portion of the breast with multiple sinuses in the region of the areola and nipple, the entire breast should be excised through an elliptical incision which removes the areola and the sinuses. Before the incision is made, a gauze compress saturated with tincture of iodine or Metaphen is sutured over the sinus area to lessen contamination of the wound. The incision is then made and the dissection is carried on outside the mammary gland to the margins of the gland and to the depth of the fascia covering the pectoral muscle. The breast is then separated from this fascia and removed. The wound is thoroughly irrigated with warm normal saline solution, closed loosely with interrupted sutures, and a drain is inserted at each end of the incision

In certain well-selected cases in which there are multiple abscesses in the breast with draining sinuses which do not tend to clear up and in which the infection is of low grade, the mammary gland may be excised without removing the nipple. The sinuses are swabbed out with iodine and encircling incisions are so made that the skin immediately adjacent to the sinuses is also removed The skin around the sinuses is approximated by continuous sutures so as to close the sinuses. The area is again cleansed, the instruments are changed and an incision is made in the crease at the junction of the breast with the chest wall, extending from the inferior to the lateral portion of this crease. The gland is separated from the pectoral fascia and the fascia is covered by wet gauze sheets. The dissection is then carried over the anterior surface of the gland, leaving as much subcutaneous fat as possible; at the same time care is taken to remove all of the mammary gland. During this part of the operation it is well to remember that the mammary gland does not have clear-cut margins. After the breast has been removed, the wound is flushed out with warm saline solution. The incision is closed by well-spaced interrupted sutures One or more rubber tissue drains should be inserted between the sutures in the most dependent portion of the incision.

Retromammary abscesses should be drained through an incision below and to the outer side, so that the breast tissue will not be penetrated and gravity will aid drainage. Sulfonamides and antibiotics should be used in these cases both pre- and postoperatively.

BENIGN TUMORS

Operations for benign tumors of the breast are planned according to the size and location of the tumor. If there is a reasonable possibility that the tumor is malignant, the incision should be made directly over the growth, disregarding the location of the scar, so that as little raw surface as possible is exposed to possible contact with cancer cells. The Thomas-Warren incision exposes an extensive raw surface, and the location of the incision makes it more difficult to perform a radical operation if the tumor should prove malignant. Where there seems to be no doubt as to the benign nature of the growth, and in chronic cystic disease of the breast, the Thomas-Warren incision is useful.

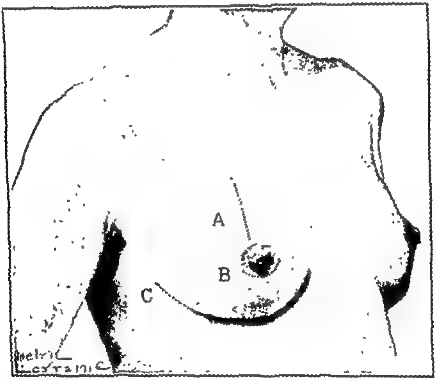

Fig. 491.—Incisions for benign lesions of the breast *A*, Radial in strap line for lesions in upper and inner portions of breast. *B*, Semilunar for lesions under nipple, areola, or for correction of inverted nipple. *C*, Thomas-Warren incision for lesions in lower and outer quadrants of breast is inconspicuous and gives excellent exposure for exploring breast tissue without cutting across ducts

In obviously benign lesions of the breast the type of incision to be used depends upon the location of the lesion. Those in the upper or inner portion of the breast are best approached by a radial incision (Fig. 491, *A*), which is made in the strap line, if possible. This type of incision will traverse fewer ducts and cause less postoperative pain The sharp dissection should be carried down to the chest wall, and the lesion, with some normal surrounding breast tissue, should be removed.

Lesions just under or near the nipple may be approached by a semilunar incision about the areola (Fig 491, *B*). This may be used when operating upon inverted nipples.

In the Thomas-Warren operation the skin incision is made along the lateral and inferior margins of the breast in the skin fold at the junction of the breast and thoracic wall (*Fig. 491, C*) and is carried down to the fascia covering the pectoralis major muscle, and the fascia covering the posterior surface of the mammary gland is exposed and dissected from the pectoral fascia. If this line of cleavage is followed, the dissection is easy as there is only loose connective tissue between the two layers of fascia. The breast is manipulated with the left hand to expose its entire undersurface and, if a growth or a localized area of chronic cystic mastitis is present, it is excised with a wedge-shaped piece of tissue, with the apex of the wedge toward the nipple and the base at the periphery of the gland (Fig. 492, *A*). The incision is

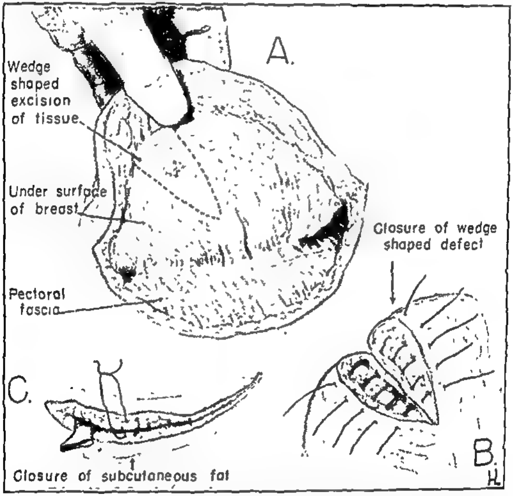

Fig. 492 —*A*, Thomas-Warren incision has been made and the dotted line shows the area to be excised. *B*, Interrupted sutures have been placed in the breast substance for reconstruction. These occasionally may be placed in two rows instead of one row as noted. *C*, The subcutaneous tissue has been closed and a drain has been placed

carried through to the fatty tissue beneath the skin, but the subcutaneous fat is not removed as it aids in refashioning the breast contour. No attempt should be made to shell out a tumor, because of the likelihood of a portion of its capsule being left behind. This may result in a recurrence, and, besides, there may be other small tumors in the adjoining breast tissue. If in operations for localized chronic cystic disease there is also inversion of the nipple, this is corrected by freeing the adhesions and placing a purse-string suture of fine catgut beneath the nipple to evert it. Care must be taken to avoid strangulation of the ducts When a segment of breast is removed, the wound is closed with interrupted fine sutures The sutures are placed

first on the portion of the gland nearest the skin, and then the capsule and the posterior part of the gland are sutured (Fig. 492, *B*). A second row of fine sutures is placed in the superficial fascia before the skin is closed, as this will help give a better breast contour. The skin wound is closed by interrupted or continuous mattress sutures of fine silk and a small rubber tissue drain is placed in the outer angle or the most dependent portion of the breast (Fig. 492, *C*).

Excision of the breast, particularly for such conditions as intracystic papilloma or extensive chronic cystic disease, may be done with but little deformity by an operation similar to that described above. The breast tissue should be completely removed but as much of the subcutaneous fat as possible should be left. After the breast has been excised and bleeding has been carefully controlled, a series of concentric fine purse-string sutures should be so placed that the inner one surrounds the base of the nipple. Care should be used in placing these sutures so that they do not penetrate the skin. None of these sutures is tied until the last one, usually the third or fourth, has been placed. The inner suture is tied first in such a way that a small opening leads through it to the base of the nipple. The remaining sutures are tied so as to form a series of concentric circles gradually increasing in size from within outward. In this way the nipple will be prevented from inverting, and a better cosmetic result will be obtained Drainage is usually necessary and is accomplished with a small rubber tissue drain. Simple mastectomy may also be performed with a satisfactory cosmetic result by an operation described by Dean Lewis. A curved incision is made at the junction of the areola with the skin to the inner side of the nipple. The areola is dissected up, the ducts are cut as they enter the nipple, and the mammary gland is pulled out gradually while the dissection is carried between it and the fat. The entire mammary gland may often be removed in this way, but, if the exposure is inadequate, a perpendicular incision should be extended downward for a short distance from the lower end of the curved incision. After the operation is completed, the wound is closed by a series of purse-string sutures of fine catgut or silk placed from within outward in the fat which surrounds the breast. With three or four purse-string sutures, the tissues are so reconstructed as to leave but little deformity. The nipple and flap of areola are sutured in position.

Occasionally, removal of the nipple is advisable in simple mastectomy for tuberculosis, large multiple benign tumors, and extensive chronic cystic mastitis as well as in multiple pyogenic abscesses. This is done by an oval or elliptical incision, the axis of which is in a line between the axilla and navel. The skin margins are dissected up on each side, as much fat as possible being retained with the skin. The operator must bear in mind that the edges of the mammary gland often extend farther than is apparent. After the pectoral fascia is reached, the breast is dissected from below upward and then from within outward and completely removed. Closure is accomplished with interrupted and/or continuous fine sutures, with drainage by rubber tissue.

In all of these operations it is most important that an abundant firm dressing be used and that the drains be removed in forty-eight to seventy-two hours.

A separate operation on inverted nipples is seldom indicated, for, if a breast is operated upon, the inverted nipple can be corrected at that time. However, certain nipples, particularly in slightly hypertrophied breasts, become so inverted that it is difficult to keep them satisfactorily clean and an operation is indicated. A small semilunar incision along the undersurface of the areola is made down into the breast tissue. The entire areolar tissue is separated to the underlying structures,

and any small adhesions close to the nipple are separated. Then several rows of purse-string sutures are placed in increasingly larger circles. The inner one, being the smallest, is first tied, and then each subsequent suture is tied so that the nipple and areola are gathered and the nipple is everted. In younger women where complete division of the ducts is contraindicated, eversion can be obtained by making a small incision on each side of the areola, removing an elliptical piece of skin, and suturing the skin with interrupted sutures. This places increased tension on the areola and causes eversion of the nipple.

CANCER OF THE BREAST

In some excellent clinics, both in this country and abroad, cancer of the breast, even in the operable stage, is treated either by irradiation alone or by irradiation combined with conservative surgery. However, most surgeons still strongly favor radical mastectomy in operable cases. Either preoperative or postoperative irradiation or both may be used in conjunction with radical surgery, for there is no unanimity of opinion as to the results obtained. Fewer and fewer clinics are using preoperative irradiation, and the use of postoperative irradiation is confined to cases with known metastasis. It is felt that it is better not to use diffuse postoperative irradiation routinely but to use it in localized areas of known metastasis, such as the axillary, supraclavicular, or parasternal regions. Intensive local irradiation may then be used with better effect. There is no question, however, but that irradiation is of great value in inoperable and recurrent mammary cancer.

If one is to treat cancer of the breast, or of any other organ, intelligently, he must be familiar with the anatomy of the regional lymphatics and must also have a clear idea of the way in which cancer spreads (Fig 493). Since Handley and others have shown, apparently quite conclusively, that lymphatic permeation is the most important method of spread in cancer of the breast and since it has also been demonstrated that the most widespread lymphatic permeation occurs along the fascial planes, it has become customary for most surgeons to remove as large an area of fascia as is reasonably possible and, as nearly as possible, to an equal distance from the tumor in all directions. In addition to lymphatic permeation, cancer of the breast is known to spread also by lymphatic embolism to the regional lymphatic nodes The lymphatic nodes so involved will depend to some extent upon the location of the growth in the breast. For example, cancer of the upper and outer quadrant of the breast may spread directly to the nodes in the apex of the axilla or even to the supraclavicular nodes, while the spread from a tumor in the medial portion of the breast may first take place to the anterior mediastinal nodes along the perforating branches of the internal mammary artery.

Fortunately, about 60 per cent of cancers of the breast occur in the upper and outer quadrant of the breast, and, therefore, in most instances the nodes beneath the lateral border of the pectoralis major muscle and in the lower portion of the axilla are the first to become involved This is fortunate, for these nodes are the most amenable to complete surgical removal. In addition to those already mentioned, there are several other groups of nodes in the axilla, those along the medial border of the axillary vein, those lying on the serratus magnus muscle, chiefly in the second and third interspaces, and the so-called central group of nodes Since these various groups communicate with each other, it is obvious that a very complete removal of the axillary lymphatic-bearing tissue, including the sheath of the vessels and the sheath covering the serratus and subscapularis muscles, is necessary.

Halsted suggested removing the supraclavicular nodes as a routine part of radical mastectomy, and while most surgeons do not do this, it might be well to remove this group of nodes at the primary operation in those cases of breast cancer located in the upper and inner portion of the breast

Handley has advocated removal of the nodes along the internal mammary artery by turning back anterior intercostal flaps While this is not done by most surgeons and probably is not entirely rational, as the associated lymphatic channels cannot be removed in continuity with the nodes, it might be wise, in those cases in which the cancer is located in the medial portion of the breast, to consider the implantation of radon seeds in these nodes or the giving of postoperative irradiation over this area.

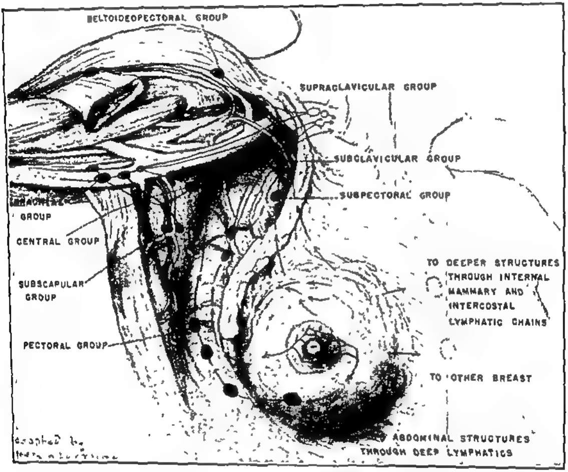

Fig. 493.—Location and arrangement of axillary and parasternal lymph nodes. Routes of lymphatic drainage from the breast to these nodes.

The ideal operation would be one in which all of the regional nodes, including the axillary, supraclavicular, and anterior mediastinal, are removed in continuity with their afferent vessels as well as a wide area of fascia, the pectoral muscles, and the breast, without cutting across the lymphatic field except at the periphery. This is obviously not possible for anatomical reasons, but the more nearly this ideal is approached, the better the results should be.

Radical Operation for Cancer of the Breast

The operation devised by Halsted and described by him in 1894 was the first rational operation for the treatment of cancer of the breast. The principles of this operation have stood the test of time and have been embodied in all of the

radical excisions of the breast which have since been described. Most of the variations have had to do with minor changes in technic, as in the type of skin incision. Handley was the first surgeon to stress the importance of excising a very wide area of subcutaneous tissue and fascia, and this is the only fundamental contribution to the surgery of cancer of the breast since Halsted's original report.

The principles stressed by Halsted were as follows: A block resection of all involved and potentially involved tissues was made so far as possible. The structures removed en bloc were the tumor, the entire breast, a very wide area of skin centering around the tumor, the subcutaneous tissue and fascia over a wide area, both pectoralis major and minor muscles, and the axillary contents. He advocated the removal of these structures in one mass without crossing the cancer field. He later advised excision of the supraclavicular glands and all lymphatic-bearing tissue beneath the clavicle at the same operation In a subsequent report he suggested that no attempt be made to fashion the skin flaps for closure and eliminated that portion of his original incision which extended out on the arm. In his later technic the lower border of the upper flap was tucked up under the vessels to protect them against infection and scar tissue contraction. No attempt was made to approximate the skin flaps and the remaining large raw area was covered by Thiersch skin grafts. He felt very strongly that infection was the most important cause of postoperative edema of the arm, and this observation seems to have been proved correct by clinical experience and also by the experimental work of Reichert and others. In advising against attempting plastic closure of the wound he recalled and endorsed a statement made by his former resident, Follis, that the person making the original incision should not be responsible for the closure.

As a result of a long and careful study of tissue excised in cases of breast cancer, Handley arrived at certain important conclusions with regard to the extent of the excision of the various tissues. He concluded that cancer cells spread in an ever-widening circle away from the original tumor as the center. He showed that the chief method of spread was by permeation along the lymphatic channels and spaces associated with the fascial planes; that lymphatic embolism was of less importance, and embolism by the blood stream of rare occurrence. From these findings he concluded that very extensive excision of the skin was unnecessary but urged that a wide, more or less circular, area of subcutaneous tissue and fascia be excised, this to be carried out by first widely undermining the skin: laterally beyond the anterior border of the latissimus dorsi muscle, medially beyond the sternum, and below to about midway between the xiphoid and umbilicus, to include all of the upper portion of the rectus sheath on the same side, the linea alba, and the medial portion of the opposite rectus sheath. Above, the undermining of the skin and fascia should extend to the clavicle and, on the shoulder, to the junction of the pectoralis major and deltoid muscles.

Many skin incisions have been recommended and most of them may be shown to have some advantage (Figs. 494 and 495). The type of skin incision, however, is of no great importance and may well be left to the preference of the surgeon, provided certain requirements are fulfilled. It should permit the excision of a wide area of skin which should bear a definite relation to the tumor and not to the nipple. It must allow adequate exposure of the axilla, chest wall, and epigastrium, and should be so placed as not to cause a dense scar in the axilla, which would limit the function of the arm and shoulder. That incision should be used, therefore, which is best suited to the individual case. For example, the Willy Meyer incision

(Fig. 494) is well suited to tumors in the upper and outer portion of the breast but is not especially adapted for those either beneath or below the nipple or in the extreme outer or inner portion of the breast. The type of incision advocated in Halsted's later reports, the Rodman incision (Fig. 495), and the Handley incision, or certain modifications of them, are suitable for the average case. Meyer's operation is well conceived in most details, but it is unwise to attempt to conserve too much skin, as Thiersch or full thickness skin grafts may be applied easily, with little or no added shock to the patient.

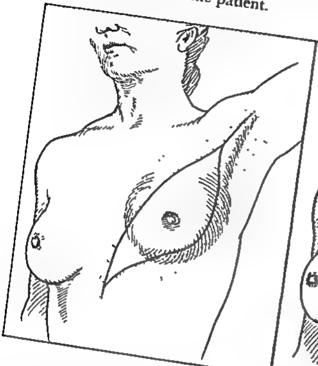

Fig. 494.

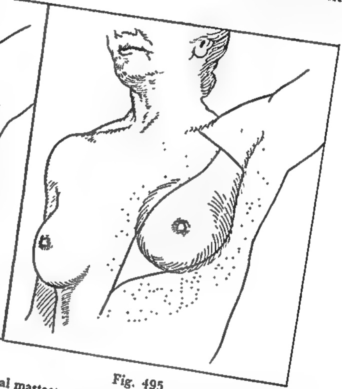

Fig. 495.

Fig. 494.—Willy Meyer incision for radical mastectomy, showing amount of skin removed. Stippled area indicates extent of the dissection; the area with breast and overlying skin is removed en masse.

Fig. 495.—Rodman incision for radical mastectomy, showing amount of tissue and skin removed, as in Fig. 494.

The operation for breast cancer, properly carried out, is a time-consuming procedure, but if absolute hemostasis is obtained at all stages, if chilling of the exposed surfaces is avoided by keeping them covered with warm saline sheets, and if the anesthetic is given properly, most patients show remarkably little shock and the mortality rate is surprisingly low. Careful control of hemorrhage is unquestionably the most important measure in the prevention of shock in such operations. As it is almost impossible to do the operation satisfactorily under local anesthesia, some general anesthetic should be used. It is important that the patient should not be deeply anesthetized as the operation consumes much time and complete relaxation is unnecessary.

The patient is placed in the dorsal recumbent position with the arm at a right angle to the body; but the arm should not be immoblized in that position until the field for operation has been completely prepared. The operative field should include the anterior portion of the chest, the anterior and lateral portions of the neck, the shoulder, the entire circumference of the arm down to the elbow, the axilla, the lateral chest wall, the lateral portion of the posterior chest wall on the involved side, and the upper half of the abdomen. One of the thighs might also be prepared for

the removal of skin grafts if it appears that a skin graft will be necessary for closure of the wound. Sterile drapes are fastened to the skin at strategic points so that they will not be displaced during the operation. If the diagnosis is established as carcinoma, the radical operation should be carried out. If, however, there is reasonable doubt of the diagnosis, a biopsy should be made. An incision is made through the skin with a sharp knife and the tumor is excised. The tumor is then incised and its gross appearance noted; if it is obviously benign, the incision is closed in layers; if it is obviously malignant, the radical operation is proceeded with. The gross appearance should always be checked by a quick frozen section examined microscopically. If the radical operation is to be done, the vessels are ligated or coagulated, the wound is packed with gauze, and the skin is closed with a snug continuous suture. Gloves and gowns are changed, the instruments and drapes are discarded, and the field is again prepared and draped.

The incision for the radical operation should be made so that it will not closely approach the biopsy incision at any point; it should extend only through the skin and a very small amount of the subcutaneous fat. The skin flaps are dissected up medially to the opposite border of the sternum and laterally to the border of the latissimus dorsi muscle. The dissection is carried upward to the clavicle, medially and above to the junction of the clavicle and sternum, and laterally on the arm to the insertion of the pectoralis major muscle. The lower medial dissection should extend to a point near the mid-epigastrium. During this dissection all bleeding vessels are clamped and ligated with fine ligatures or coagulated as the operation proceeds, so the field will not be obscured by hemostats. The exposed area is kept covered with warm saline sheets. After the flaps have been elevated, the entire area is outlined further by incisions which extend through the fat and fascia. The upper outlining incision is made at the junction of the pectoralis major and deltoid muscles, then along the lower border of the clavicle, and across to the opposite border of the sternum. The medial incision exposes the opposite border of the sternum but does *not extend sufficiently far to divide the perforating vessels.* The lateral incision extends along the border of the latissimus dorsi muscle, and the abdominal incision through the fat and fascia to the opposite side of the midline, including the entire upper portion of the rectus sheath on the involved side, the linea alba, and a small portion of the opposite rectus sheath. The fascia is dissected from the sternum and the dissection is then carried down onto the abdominal wall on the opposite side of the midline so that a small portion of the opposite rectus sheath, the linea alba, and the upper portion of the rectus sheath on the diseased side are dissected up to the level of the costal margin.

The pectoralis major is separated from the deltoid, and the outer tendinous portion of the muscle is severed close to its insertion. If all of the muscle is to be removed, the incision is carried medially along the lower border of the clavicle, then down along the border of the sternum for a short distance. The pectoralis major muscle is turned downward to expose the upper portion of the pectoralis minor muscle, which is separated carefully from the fascia and divided near its insertion. This muscle is retracted to show the axillary fascia, which is incised from the apex of the axilla downward and outward along the upper border of the axillary space to the border of the latissimus dorsi muscle. The dissection begins at the apex of the axilla immediately beneath the clavicle, the loose tissue and fascia including the fascia over the serratus muscle is dissected downward over the inner wall of the

axilla and downward and outward over the posterior wall of the axilla. The loose tissue is dissected off of the cords of the brachial plexus first, then down over the artery and vein. The entire sheath of the vein should be carefully removed with a sharp knife. The branches from the axillary artery and vein are exposed, doubly clamped, divided, and ligated. Extreme care should be used in this portion of the dissection to avoid discoloration of the axillary tissues by blood, for if this should happen, the remaining portion of the dissection will be more difficult. It is especially important to ligate promptly the proximal segments of the veins entering the axillary vein, as many of them are thin-walled and may be torn away easily.

The long thoracic nerve is exposed as it passes downward on the upper medial wall of the axilla on the anterior serrations of the serratus magnus muscle. This nerve should be spared, and, as it is closely adherent to the muscle, its preservation offers no especial difficulty. As the dissection is carried downward and outward below the great vessels, the subscapular vessels are exposed and the thoracodorsalis nerve is found lying in close relation to them. These vessels should be carefully dissected out, individually clamped, divided, and ligated. The thoracodorsalis nerve is important as it innervates the latissimus dorsi muscle, so if the lesion is an early one and there is no evidence of involvement of the tissues immediately surrounding the nerve, an attempt should be made to preserve it. If, however, there are any enlarged adjacent nodes, or if there is involvement of the surrounding tissues, the nerve must be sacrificed, for preserving it under such circumstances would probably mean an incision across the cancer field. All loose tissue and fascia are removed from the axilla en masse with the pectoral muscles (Fig. 496). After the axillary dissection has been completed, the remaining portion of the sternal attachment of the pectoralis major muscle is separated and both pectoral muscles are detached from the underlying ribs. It is important to expose the perforating vessels and clamp them before they are divided, for otherwise they may retract beneath the intercostal structures. These vessels may be either ligated or coagulated thoroughly. Ligation prevents subsequent hemorrhage with greater certainty but thorough coagulation also destroys the accompanying lymphatics. The entire mass of tissue is now removed including the axillary contents, both pectoral muscles, subcutaneous tissue, fascia, and breast. The wound is thoroughly flushed out with warm normal saline solution. A small stab wound is made below the axilla just at the border of the latissimus dorsi muscle. A No. 14F or 16F catheter is inserted into this wound and carried into the axillary space. The catheter is sutured to the skin to prevent slipping, and suction is applied to the catheter every two hours for the first forty-eight hours (Fig. 497). This, first advocated by Murphey, keeps the skin flap firmly against the chest wall and there will be less serous drainage and better healing of the wound. An additional rubber tissue drain is placed at the lowest angle of the incision since frequently serum will collect at this point. The skin margins are approximated with interrupted sutures of nylon or silk and continuous fine silk. If it is found that the skin cannot be closed, the margins of the skin should be sutured to the underlying tissue and the defect covered with split thickness skin grafts. When there is slight increased tension in the skin flaps, small stab wounds at the points of most tension seem to be beneficial.

One of the objections to the procedure which has been outlined is that the upper portion of the lateral skin flap, which has a relatively poor blood supply, is exposed for the duration of the operation and may become sufficiently chilled to inter-

fere with subsequent healing, and the wound margins may become necrotic. Necrosis of the skin edges leads to infection and, as shown by Halsted, this is apt to lead to postoperative edema of the arm. To avoid this the operation may be modified without especial difficulty. It is carried out as described above except that the lateral skin flap is not elevated until the axillary dissection has been completed. After this has been finished and the pectoral muscles have been separated from the underlying structures, the wound may be covered by warm saline sheets, the breast replaced in position, the lateral skin flap then elevated, and the axillary structures, pectoral muscles, and breast removed by carrying the incision through the fat and fascia at the border of the latissimus dorsi muscle. The remainder of the operation is finished as previously described.

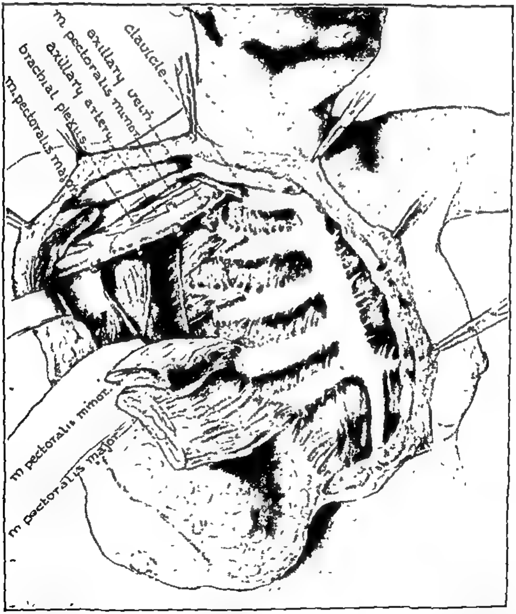

Fig 496.—Radical operation for carcinoma of the breast. Note that the fascia has been removed beyond the opposite border of the sternum, the sheath of the upper portion of the rectus muscle on the side of the operation and the medial portion of the sheath of the opposite rectus muscle have also been removed The sheath has been removed from the great vessels and all of the lymphatic-bearing tissue is removed from the axilla. The long thoracic and thoracodorsalis nerves have been preserved. The breast, pectoral muscles, and axillary tissues are still attached to the lateral skin flap.

A snug dressing is applied with moderate compression using abundant dressing or a marine sponge in the axilla. Firm, constant pressure over the entire wound insures better healing and there is less postoperative edema. The sutures should be removed in from eight to ten days.

If the line of closure is kept anterior to the axilla and the collection of serum is held to a minimum, there should be no limitation of motion to the arm, and post-

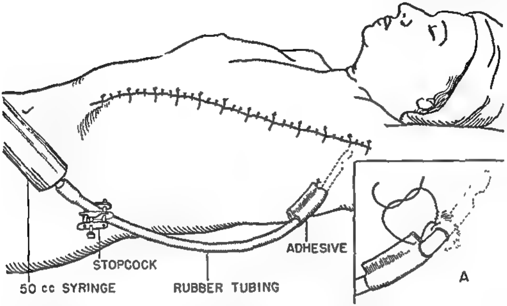

Fig. 497.—Catheter in place and negative pressure used in axilla by means of suction. This reduces drainage and insures better adherence of skin flaps to chest wall. Inset *A* shows method of attaching catheter to skin without puncturing catheter with suture.

Fig 498 —Photograph of patient on whom the Rodman operation was done, taken eleven months after the operation. Note the line of scar which shows that the incision was completely closed at the time of operation and the mobility of the arm which is unimpaired by the operation.

operative edema should be negligible (Fig. 498). The use of suction with negative pressure (Fig. 497), as previously described, has been found most helpful in reducing postoperative swelling of the arm.

In recent years electrosurgery has assumed an increasingly important place, especially in the treatment of malignant disease. Kelly and Ward enthusiastically recommend it in the radical operation for carcinoma of the breast. It unquestionably has a place in radical mastectomy, but the author feels that by sharp scalpel dissection a neater and cleaner operation can be performed and there is less postoperative serous drainage. The axilla is best dissected with a sharp scalpel and the vessels are ligated. The breast and pectoral muscles are separated from the chest wall by ordinary dissection but the perforating branches of the intercostal and internal mammary arteries are usually coagulated. When used in this way electrosurgery saves considerable time in the performance of a radical mastectomy and does not seem to add to the danger of the operation.

It has been shown by Coller and others that the amount of blood loss during a radical amputation of the breast is usually from 500 to 1,000 c.c., even in the hands of the most careful operators. For this reason, a blood transfusion of at least 500 c.c. should be started during the latter part of the operation and timed so that it will be completed by the end of the operation. If there is no contraindication, additional intravenous fluids are administered before and after the transfusion.

Bilateral Oophorectomy

Within recent years the author and his associates have found it advisable in cancer of the breast cases to do surgical castration on all women in the premenopausal period. This has been our routine procedure since 1937, and the five-year survival rate of these cases is better than that of older women in the postmenopausal stage.

In patients who are to have a surgical castration, the entire abdomen is prepared for operation along with the breast area. Drapes are so placed that a short lower midline incision can be made, and a laparotomy sheet is placed over this area, with the opening over the abdominal area. A sterile towel is placed over this opening, and the draping and operation for the radical amputation of the breast is then carried on as usual. After the breast has been removed and the bleeding controlled with ligatures, either the assistant or operator removes the sterile towel from the laparotomy sheet opening and proceeds, through a small midline incision, to remove both ovaries while the other closes the breast wound. The bilateral oophorectomy is carried out by bringing each ovary into the wound, clamping the ovarian ligaments, and excising each ovary. The ovarian ligaments are sutured with catgut and then dropped back into the peritoneal cavity. The abdominal wound is closed in layers, and unless some unusual adhesions or other pathology is encountered in the pelvis, this portion of the operation is usually completed at just about the same time that the breast skin wound has been closed and does not prolong the time of the operative procedure.

MASTOPEXY

Plastic operations on the breast are definitely indicated in certain conditions, particularly where the breasts have hypertrophied to such a size that proper support cannot be maintained without discomfort to the patient. Some type of mas-

topexy is also occasionally indicated on breasts which have become so pendulous that proper support is impossible. Several different types of operations have been advised, but apparently the most satisfactory is a modification of the Maliniak technic. By following this procedure, the breast can be raised to its normal position,

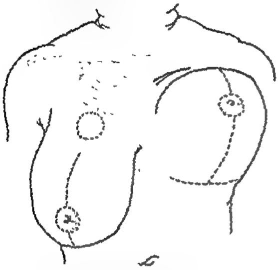

Fig. 499

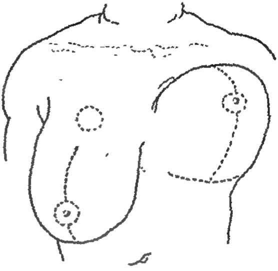

Fig 500.

Fig 499.—Mastopexy. *Line of incision on left, while breast is pulled downward, and on right while held upward.*

Fig 500—Mastopexy. *Stippled areas show extent of undercutting necessary.*

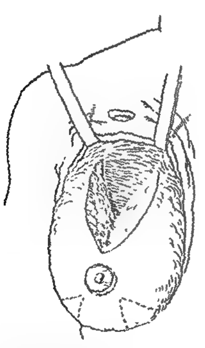

Fig. 501.

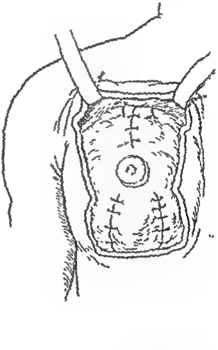

Fig. 502.

Fig. 501.—Mastopexy. The upper wedge of tissue has been removed and the lower two have been outlined.

Fig 502—Mastopexy. The breast substance has been *sutured together* and the upper edge attached to the pectoral muscle just below the clavicle.

its contour reestablished, and its function maintained. The operation may be done in either one or two stages, but unless there is a contraindication, a one-stage operation seems to be the procedure of choice. In the one-stage operation a circle is

marked with gentian violet, the diameter of the nipple and areola, in the midclavicular line over each breast at the level of the fourth rib. This is done with the breast pulled downward so that the skin is held taut. A vertical incision is then made from 5 to 7 cm. below this circle down to the areola. An incision is made around the areola and continued down to the mammary fold (Fig. 499). The skin flaps are dissected in all directions so that the skin over the entire breast is dissected up, taking care to leave enough subcutaneous tissue attached to the skin so that there will be no impairment of the circulation. The dissection is carried up to the undersurface of the clavicle (Fig. 500). In order to dissect the skin up, a transverse incision in the undersurface of the mammary fold is often necessary After the skin has been completely separated from the breast, wedge-shaped sections are removed from each lower quadrant of the breast, and a larger wedge-shaped section is removed from the upper portion (Fig. 501). The breast is reconstructed with fine sutures. The upper edge of the breast is then firmly attached to the pectoral muscles just under the clavicle to prevent future sagging (Fig. 502). The nipple and

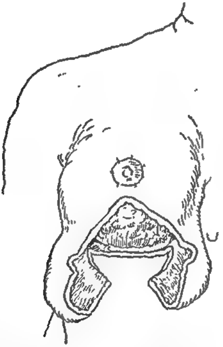

Fig. 503.

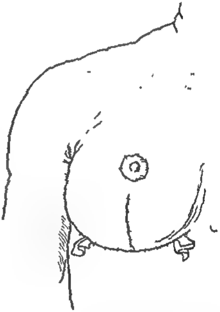

Fig. 504.

Fig. 503.—Mastopexy. The nipple and areola have been sutured in place and the skin has been drawn over the breast tissue.

Fig. 504—Mastopexy. The excessive skin has been excised, the skin sutured, and the drains have been placed in each angle of the wound

areola are placed into their new position in the skin and sutured with interrupted silk (Fig. 503). The excessive amount of skin from the lower portion of the breast is then excised. It is important to remove an adequate amount of skin so that there will be no sagging, but care should also be taken not to remove too much skin and produce tension on the suture line. The skin of the lower portion of the breast is sutured so that the final incision is an inverted T (Fig. 504). The same procedure is repeated on both breasts, and, as a rule, the entire operation can be completed at one stage. If it is to be done in stages, the wedge-shaped sections of the breast on the lateral and lower surfaces are not removed until the second stage. It is important that rubber tissue drains be placed in

the lower angle of the wound and that abundant firm dressings be applied so that there is even pressure over the entire breast and the breast is held in its desired shape and position by the dressings.

EXCISION OF LESIONS OF THE MALE BREAST

Surgery of the male breast is simpler than that of the female breast, as in the former there is little need to try to save portions of the breast. If surgery is necessary, the operation should be either simple or radical mastectomy. When there is an actual neoplasm present and cancer is probable or suspected, it is best to do a simple mastectomy with immediate biopsy. If malignancy is found, a radical amputation with dissection of the axillary contents and the pectoral muscles should be carried out. This operation is the same as the radical procedure done on female breasts, which is described in the first portion of this chapter. The Willy Meyer type of incision is the one preferred in the male.

Simple amputation of the male breast is most frequently done for gynecomastia, although other benign lesions may require local excision or amputation. It is best to remove all of the areolar tissue and the nipple, as any attempt to save these structures may result in small sloughs of the areola next to the incision or a painful and annoying nipple. If it is desirable to preserve these structures for cosmetic or psychic reasons, a slightly curved incision is used just below the areola. The dissection is carried down to the pectoral muscle and then upward and lateral to undermine all of the breast tissue. It is important not to curve the skin incision too much, for, if this is done, the blood supply to the areola and nipple will be impaired and a slough of these structures will occur. After all the breast tissue has been mobilized, it is dissected away from the upper skin flap and removed in one block. When the nipple and areolar tissue are to be removed, a second curved skin incision is made, beginning at the ends of the original incision and curved upward so that all of the skin over the breast tissue is removed along with the nipple. The subcutaneous tissue is closed with interrupted sutures to obliterate all the dead space, the skin is closed accurately, and an abundant, firm dressing is applied. If the patient is fat and the subcutaneous tissue is difficult to close, it may be necessary to undercut the edges for several centimeters to produce satisfactory relaxation Except in the very thin individual it is best to use a small rubber tissue drain in the outer angle of the incision. If a bilateral mastectomy is to be done, as may be required for cosmetic reasons, a transverse incision is definitely preferable, but when one breast is removed some surgeons advocate a diagonal elliptical incision and the resultant closure is along the edge of the pectoralis major muscle.

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CHAPTER 45

HERNIA

Herbert C. Lee

The operative repair of hernias is one of the most commonly performed operations in all surgery. It is one of the first procedures to be turned over to house officers and junior staff men, yet there are few operations which require more flexibility in technic and more acumen in recognizing the existing anatomical defects These qualities can be achieved only by experience, and thus it is essential that adequate supervision be given to younger surgeons in training so that they may be well grounded in the basic fundamentals of hernias, have a detailed knowledge of the various procedures that may be used to repair a given defect, and properly learn the delicate technic required.

Hernias may appear through areas of developmental weakness or through surgical incisions in the abdominal wall. They occur more frequently in the inguinal, femoral, and umbilical regions, but they occasionally protrude through the obturator canal, the triangle of Petit, and other openings in the abdominal wall. This chapter will deal with repair of the commoner forms of hernia. The descriptions of the rarer hernias are well covered in the literature and in the various monographs on hernia. Hernias of the diaphragm are discussed in the chapter on thoracic surgery.

The repair of hernias is essentially surgical in nature, and, with proper preparation and postoperative care, few patients now need suffer the discomfort and dangers of hernia, including the prolonged wearing of trusses. Although the detailed technic of herniorrhaphy naturally differs in the various anatomical areas, there are certain general principles that apply to all such operations. Complete removal of the sac, or at least obliteration of the neck of the sac, is essential. Complete closure or marked reduction in the size of the opening in the abdominal wall, as in the inguinal or femoral canal, is also important, and whenever possible, fascia should be united to fascia in such closures Thus the surgical treatment of hernias resolves itself into the removal of the sac and the repair of the defect in the abdominal wall

The statement that it is not so much the method which gives results as the care with which it is carried out applies especially to operations for hernia. Any of the standard methods of repair will give good results when properly and carefully performed

The basic principles of hernia repair are fairly well standardized, depending on the anatomy of the area involved, but since each hernia should be treated as an individual problem, there is no rigid standardized technic for every case. Most surgeons vary the technic according to their own experience and results, and it is

because of the combined experience of many of these surgeons that the modern trend in this field of surgery is toward a simplification of procedures and the establishment of definite criteria for the repair of the hernia according to its type.

The diagnosis of a hernia is sufficient indication for surgery. The operation is an elective one, however, unless strangulation is present, and although we feel that operation should be done as soon after diagnosis as possible, it should not be done until the patient is in the best possible condition for the operation.

The foremost indication for immediate operation in patients with a hernia is the presence or danger of strangulation. The incidence of this complication is high in umbilical and femoral hernias, relatively low in indirect inguinal hernias, and rare in direct hernias. Strangulation which cannot be reduced by elevation of the feet, adequate sedation, and gentle manipulation should be considered an indication for immediate operation. There is little excuse for delay in the treatment of strangulated external hernia, for the diagnosis should be made readily. If a closed reduction is accomplished, the canal should be examined to ascertain whether the structures are completely reduced. Even though the canal appears empty, if symptoms persist an immediate operation is indicated.

In an operation for strangulated hernia, the sac should be carefully opened before the constricting ring is divided, as the ring can then be divided more safely under direct vision. Furthermore, if the stricture is divided first, the bowel may slip back into the abdominal cavity before it has been examined. If the strangulated bowel is dark but not definitely gangrenous, a catgut loop may be inserted through the mesentery and the bowel replaced in the abdomen, the long ends of the catgut remaining outside so that the involved segment can be delivered and examined at intervals If the operation is done under local anesthesia, and almost all strangulated hernias should be thus operated upon, the wound may be covered with warm saline sheets and sufficient time allowed to determine the viability of the intestine. The administration of pure oxygen through a gas mask will hasten the return of a normal color. If the bowel is viable, its color will rapidly improve, muscle tone will return, and mechanical stimulation of the bowel will cause peristaltic waves to pass completely across the involved area. If the viability of the entire loop is questionable, a resection should be done The details of the technic for this procedure are described in the section on intestinal surgery. If the bowel is gangrenous or perforated and a resection is done, a temporary closure of the abdominal opening may be made with no attempt to repair the hernia. The herniorrhaphy may be done after all infection has subsided. This procedure is not absolutely as necessary as it was prior to the introduction of the antibiotics, but an infection in a hernia wound can be serious, and, unless one is sure of the degree of contamination, it would seem advisable to be conservative and not risk an infection which the antibiotics might not control.

Age is no longer a factor in advising operation for hernia Regardless of the age of the patient, modern surgery, with modern anesthesia, technic, and drugs, is available to practically all patients with a hernia. In newborn infants it is preferable to postpone operation until the birth weight is regained. In patients of advanced age operation is advised if the general physical condition is good and the symptoms of the hernia are incapacitating. Many older patients prefer the risk of operation to the discomforts of the hernia and practically all repairs in this age

group are feasible with local anesthesia. Herniorrhaphy is advised in all patients with hernia, provided there is no true contraindication in their general condition.

The presence of a large subcutaneous inguinal ring without evidence of a hernia is no indication for surgery. Since there is wide variation in the normal size of the ring, there is no evidence that a large ring is abnormal or that it predisposes to future herniation.

There is some controversy as to whether bilateral hernias should be repaired in one or two stages. Since the type of Cooper's ligament repair advised utilizes all of the fascial planes in the inguinal region on one side, it is felt that a similar procedure on the opposite side at the same operation might weaken the first side. Consequently, it is best to repair bilateral inguinal hernias in two stages, six to seven days apart. Since local anesthesia is preferred for almost all inguinal hernias, this method of operation does not entail two general anesthetics and consequently one objection to the two-stage procedure is overcome. In infants, children, and in young adults who have good tissues, repair of both herniaı at the same operation is advised, but in all others the two-stage operation is preferred.

In long indirect sacs, and in congenital hernias with or without hydrocele, it is not always necessary to remove the distal portion of the sac. It is of utmost importance to perform a high ligation of the sac and remove the proximal end distal to the ligature.

One of the major advances in the repair of hernias is found in the more general use of nonabsorbable sutures. Catgut has little place in hernia surgery, since the absorption time is unreliable in plain catgut, and chromicized catgut is somewhat irritating to the tissues. Kangaroo tendon has a longer absorption time but it produces a bulky knot when tied and occasionally acts as a foreign-body irritant to the tissues. Silk is less irritating and may be tied more securely with smaller knots than catgut or tendon. When used under the proper conditions, namely, rigid aseptic technic and careful handling of tissues, it gives a lower incidence of infection and a higher percentage of cures than other suture materials. Cotton has the same advantages as silk and is preferred by many surgeons. It is not handled as easily as silk but is an entirely satisfactory suture. Stainless steel wire is also preferred by some surgeons because of the almost complete absence of tissue reaction, but while it is an adequate material, it has no real advantage over silk or cotton. Autogenous fascia has been used for hernia repair. Gallie and LeMesurier felt that fascia was especially indicated in direct, recurrent, or large indirect hernias, and they cut strips of fascia lata 0.5 cm. wide and 30 cm. long and used them as sutures in performing a Bassini operation. McArthur closed the inguinal canal with a pedicled fascial suture taken from the cut edges of the aponeurosis of the external oblique, leaving them attached at the pubis. Fascia, however, is apparently often absorbed, as shown by Burdick et al, and the incidence of infection and recurrence is higher when it is used. Silk, cotton, and stainless steel wire, therefore, are the preferable suture materials.

Tension should be avoided as much as possible in repairing hernias. Although there are times when some tension is necessary to close a defect, this may result in poor healing and a consequent higher incidence of recurrence. If too much tension is required to repair a hernia properly, the use of a relaxing incision in the anterior rectus sheath is recommended.

A necessary amount of dissection must be done to remove areolar tissues from important structures such as muscle and fascia. This dissection is necessary to allow the structures to come into close contact with each other and thus form a firm type of union, but the dissection of the areolar tissue should be limited only to those structures in which close apposition will take place, as in the imbrication of the external oblique aponeurosis, or where it is necessary to identify and preserve certain anatomical structures, such as Cooper's ligament.

Occasionally a patient will be found to have such poor tissues that a recurrence seems unavoidable. Although a careful and adequate herniorrhaphy with silk sutures will usually be sufficient regardless of the type of tissues, many surgeons have employed various methods to overcome the hazard of poor tissue, such as fascial pedicles and flaps, fascial transplants, autogenous and preserved fascial strips, Vitallium plate, tantalum mesh, cutis grafts, and whole thickness skin grafts. For the reasons already cited, the use of fascia has its limitations, but there seems to be a definite place for the use of cutis or whole thickness skin grafts and tantalum mesh.

As already stated, local anesthesia is preferred for the repair of inguinal hernias in all but the very young. It gives complete anesthesia and lessens the anesthetic risk. Nevertheless, in recent years, intravenous Pentothal Sodium anesthesia has been used for herniorrhaphy in good-risk patients in the young adult and middle age groups. This is a very satisfactory anesthetic and in competent hands is relatively safe. It is particularly useful in bilateral inguinal and femoral hernias and in large umbilical and ventral hernias. In infants and children Vinethene induction and open drop ether is employed. In the aged local anesthesia is used exclusively. Spinal anesthesia has also been recommended in those cases in which local anesthesia is not practicable, but intravenous anesthesia is gradually replacing spinal anesthesia for hernia operations.

The technic of local anesthesia is as follows: One-half per cent procaine solution, containing 1 to 2 minims of Adrenalin to the ounce, is employed for local infiltration and blocking the regional nerves. This solution is injected intradermally along the line of the incision. A needle is then inserted in this same line about 3 cm. below and medial to the anterior superior iliac spine and penetrates the aponeurosis of the external oblique muscle. About 10 c.c. of the anesthetic solution are injected slowly into this area to block the ilioinguinal and iliohypogastric nerves. The subcutaneous tissue is infiltrated with the procaine solution, special care being used to anesthetize the area around the external ring. After the sac is picked up and dissected away from the cord, a fine hypodermic needle is inserted through the peritoneum at the neck of the sac and the surrounding tissues are infiltrated. No other anesthesia is necessary.

Early ambulation is practiced in all of our hernia cases. The patient is allowed to get out of bed to urinate, if necessary, the day of operation, and after that time he is allowed bathroom privileges. It is preferred that he either lie flat in bed or walk. Chair sitting, as well as Fowler's position, is discouraged. In the uncomplicated case the sutures are removed on the fifth to the seventh postoperative day, and the patient is allowed to go home immediately thereafter. He is restricted from heavy work for three weeks after leaving the hospital and after that time is allowed unrestricted activity. In the case which requires only a herniotomy, there is little need for any restriction of normal activity after leaving the hospital.

There are three anatomical types of inguinal hernia. The *indirect* type is the ;t commonly encountered, especially in children and young adults. In this type bowel enters the internal ring, passes down the canal and out through the ex- ıal ring, and eventually reaches the scrotum. *Direct* hernia is rarely found in dren or young adults, and occurs most often in individuals past thirty years of . In this type the sac originates medial to the deep epigastric artery, passes out ugh Hesselbach's triangle, and emerges through the external ring. In long- ıding direct hernias, the examining finger can be inserted through the external ; directly into the abdominal cavity, and as the hernia emerges it bulges directly and does not tend to pass down into the scrotum. *Sliding* hernia is apt to oc- in elderly individuals and often involves the bladder. On the left side the des- ding colon and sigmoid, and on the right side the ascending colon, cecum, and ninal ileum may be found in this type of hernia. It may appear in either the oral or inguinal region, usually the latter. The most important characteristic ıat an abdominal viscus actually forms a part of the wall of the sac; such a vis- must be at least partially extraperitoneal.

Since the studies by McVay and Anson on the anatomy of the inguinal and oral regions, it has become necessary to discuss femoral hernias with inguinal nias as they are practically all directly related to a defect in the same layer, ıely the transversus abdominis aponeurosis and its investing fasciae in the area Hesselbach's triangle. The only exceptions to this fact are the indirect inguinal nias which emerge through a small internal ring. These latter represent the jority of inguinal hernias and should have no recurrence if properly evaluated at time of operation and properly treated by a high ligation of the neck of the sac s either a closure of the internal ring medial to the cord or a modified Ferguson niorrhaphy.

A direct inguinal hernia presses forward though the weakened transversus ab- ninis aponeurosis and fascia, a large indirect inguinal hernia encroaches upon it n the lateral side, and a femoral hernia has the femoral ring enlarged medially : to a narrowing of the insertion of this layer into Cooper's ligament.

lirect Inguinal Hernia

The surgical treatment of inguinal hernia was unsatisfactory until 1889 when ;sini and Halsted independently and almost simultaneously reported the results ained by their radical operations, which were similar in fundamental principles l varied only in minor technical details. The most important steps in both of the rations were high ligation and excision of the sac and repair of the weakened a in the abdominal wall. These two operations differed in the fact that Bassini nsplanted the cord between the internal oblique and the aponeurosis of the exter- oblique muscle, while Halsted transplanted the cord in a subcutaneous position ernal to the aponeurosis of the external oblique Both men sutured the internal ique muscle to the inguinal ligament and closed the external oblique aponeurosis hout imbrication. Subsequently, Coley (1898) reported cases in which he left cord in its bed, but Ferguson (1899) is credited as being the first to adopt non- nsplantation of the cord as a routine procedure. Andrews (1895) receives credit the imbrication of the aponeurosis of the external oblique muscle. Halsted had

experimented with nontransplantation of the cord from the beginning, but it was not until 1903 that he rejected his original operation and adopted one essentially the same as a combined Ferguson and Andrews procedure. Bloodgood advised suturing the lateral border of the rectus muscle and sheath to Poupart's ligament to strengthen the structure over Hesselbach's triangle, but Halsted modified this by reflecting a flap of anterior rectus sheath over this weak area, suturing the flap to Poupart's ligament. La Roque separated the lower fibers of the internal oblique and transversalis muscles and incised the peritoneum above the internal ring, thus exposing the neck of the sac from above, or the abdominal side, which made it possible to excise the neck of the sac intraperitoneally and repair the hernia from without. The chief value of this procedure was to stress the importance of complete removal of the sac.

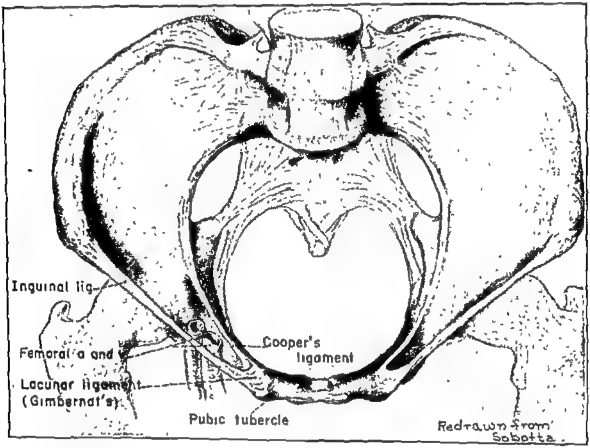


Fig. 505 —Human pelvis showing relationship between Cooper's and *inguinal ligament.*

Hernia repairs in the ensuing years were based on these general principles, and of them all the Bassini procedure was the one most widely used. In the earlier editions of this book much space was allotted to detailed descriptions of the Bassini operation as well as to a modification of the Ferguson technic. At about the time of the last edition, however, McVay and Anson revived interest in a Cooper's ligament repair originally described by Lotheissen (1898), and the more general adoption of this method in the past decade has been one of the advances in the treatment of inguinal hernia. It was definitely shown that Cooper's ligament is in the same fascial plane as the conjoined *tendon*, while Poupart's ligament is in a superior fascial plane along with the aponeurosis of the external oblique and the fascia lata.

It became obvious, therefore, that it was more logical to suture the conjoined tendon to Cooper's rather than to Poupart's ligament, thus eliminating the troughlike pouch which is formed if the latter ligament is used.

The Cooper's ligament repair may be used for direct inguinal hernias, femoral hernias, recurrent groin hernias of any type, and in indirect hernias in older peop in those with weak structures, or in those with an internal ring larger than 2 cm It should not be used in indirect hernias in infants, children, or in healthy youn adults with strong tissues where a simple herniotomy with or without a Ferguso repair is sufficient.

Although the Bassini, Halsted, and Ferguson operations all have merit, and are preferred by many surgeons for certain types of inguinal hernia, it is felt that their use should be reserved for selected individual cases in which the particular anatomical defect can best be corrected by one or the other procedure.

The routine use of the Cooper's ligament operation, wherever it is feasible in all groin hernias, has been found to be an extremely satisfactory procedure. Although one must be prepared to do all types of herniorrhaphy, with the use of this one procedure more hernias are repaired correctly with fewer recurrences than has heretofore been possible. One serious objection may be raised to the frequent use of Cooper's ligament in hernia repairs, and that is that the necessary handling of the femoral vessels may lead to an increase in the incidence of thrombophlebitis (Fig. 505). This, however, has not been the experience of the author, nor has it been reported in the literature.

Direct Inguinal Hernia

Since employing the Cooper's ligament repair, it has been used routinely for direct inguinal hernias as well as indirect hernias In fact, it is more important to use this technic in direct hernias than in the indirect ones, since the prime purpose of the Cooper's ligament repair is to reinforce Hesselbach's triangle and thus correct the anatomical defect If the Cooper's ligament operation is not used in direct hernias, and there are many surgeons who still prefer the various modifications of the older classical operations, it is important to transplant the cord even though it may not be transplanted in indirect hernias. As the conjoined tendon is apt to be deficient in direct hernias, it is often necessary to use either the rectus muscle or a flap from its anterior sheath for additional support, and it is also important to imbricate the aponeurosis of the external oblique muscle to support the underlying structures. As has been stated, however, any procedure which does not utilize Cooper's ligament in the repair of direct hernias is based on unsound anatomical considerations and is necessarily doomed to a higher number of failures

Recurrent Hernia

The repair of recurrent hernias often taxes the ability and the ingenuity of the surgeon. Oftentimes one to five different attempts have already been made to repair an inguinal hernia, and at each attempt a different type of herniorrhaphy may have been tried The anatomical structures have usually been greatly weakened if not totally destroyed, and thus a great many different technics have been devised to reconstruct these weakened tissues

Hernias will recur as indirect hernias if the sac was improperly removed at the first operation, but if the sac was properly ligated they will usually recur as direct hernias, because of the natural tendency of all hernias to progress in this manner. Most hernias will recur because of the use of absorbable sutures, too much tension, failure to remove the areolar tissue from fascia prior to suture, or because of poor tissues in general. It is felt that most recurrent hernias should be repaired by the Cooper's ligament type of operation

Cooper's Ligament Method

After routine preparation of the skin, an incision is made from 1 cm. medial to the anterior superior spine downward and medially to just below the pubic spine (Fig. 506). This is a longer incision than that used in the classical Bassini operation, but since it allows more adequate exposure, less retraction is necessary, and consequently, less damage is done to the tissues. Exposure in the lower end of this incision is of much more importance in the Cooper's ligament repair than in other types, as there is considerably more chance of serious injury to vital structures unless they are exposed to direct view. The incision is carried through the subcutaneous tissue to expose the aponeurosis of the external oblique. The external ring is exposed and the external oblique aponeurosis is opened in the upper part of the wound (Fig. 507). This opening is made sufficiently large so that the handle of the scalpel can be passed beneath the fascia down to the external ring. This procedure separates the iliohypogastric and ilioinguinal nerves from the undersurface of the aponeurosis. The aponeurosis is then divided in line with its fibers down through the external ring. This incision should divide the external ring at its upper border to allow for an adequate lower flap.

The aponeurosis is dissected from the underlying muscle laterally and below as far as Poupart's ligament, and medially and above to expose the lateral border of the rectus sheath. The cord and surrounding structures are separated from the lower leaf of the aponeurosis and Poupart's ligament, as well as from the areolar tissues around the pubic spine and conjoined tendon. The ilioinguinal nerve is carefully dissected from its bed and is kept out of the field by being placed behind a small hemostat which grasps the medial cut edge of the external oblique aponeurosis. If the iliohypogastric nerve is seen, it too should be retracted where necessary. The sac, which lies anterior and medial to the cord just below the inferior border of the internal oblique muscle, is then picked up and incised. It is often necessary to search as high as the internal ring for an indirect sac. If no sac is identified after the entire length of the cord is searched, it is necessary and helpful to open the peritoneal cavity through the fibers of the internal oblique and transversalis muscles just above the level of the internal ring, as advised by La Roque. The sac can usually be identified by examination of the hernia area with a finger inside the peritoneal cavity. The finger pushes on through the sac and it is picked up from below with a hemostat The peritoneal opening and the divided muscles are then closed. The sac is freed by combined sharp and gauze dissection and its neck is carefully exposed. While the sac is open, a finger should always be inserted into the peritoneal cavity to feel Hesselbach's triangle for a direct weakness or hernia and to feel the femoral ring (Fig 508). If a direct sac is present, it should be brought out lateral to the inferior epigastric vessels into the lumen of the indirect

sac, thus converting the two sacs into one (Fig. 509). Similarly a femoral sac can be converted into an indirect sac. The direct sac is seldom opened, as transposition is all that is necessary.

It is necessary at this time to determine also the size of the internal ring and to decide whether reconstruction of the posterior inguinal wall is necessary. The opening in the end of the sac is enlarged so that any omental or bowel adhesions may be freed. If a sliding hernia is present, it should be handled according to the manner described later.

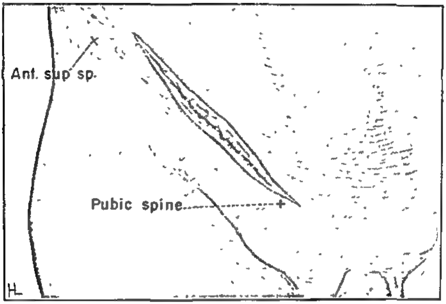


Fig. 506—Inguinal herniorrhaphy. The skin incision

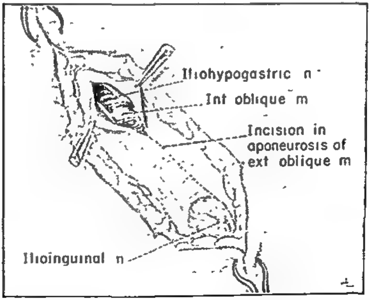


Fig. 507—Inguinal herniorrhaphy. Incision in the aponeurosis of the external oblique muscle. Side sheets are used routinely but will be omitted from subsequent illustrations.

The indirect sac is closed as high as possible to prevent indirect recurrences (Fig. 510). The sac is transfixed by a doubled 000 silk suture which is tied on both sides of the sac and the sac is cut away (Fig. 511). The ends of the silk ligature are left long and are passed through the internal oblique muscle from behind forward

a short distance above the lower border of this muscle and slightly apart. The needle is passed eye first so as to avoid injury to any blood vessel within the muscle (Fig. 512). The two sutures are tied anterior to the muscle, thus anchoring the neck of the sac to the posterior surface of the internal oblique muscle. In cases of com-

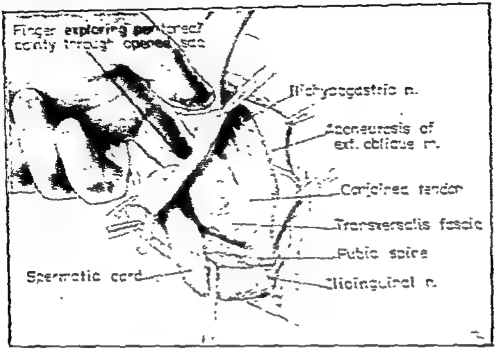


Fig. 508.—Inguinal herniorrhaphy. Finger inserted through opened indirect sac to explore for possible direct or femoral sac.

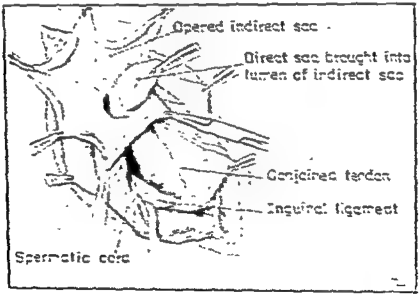


Fig. 509.—Inguinal herniorrhaphy. Combined direct-indirect hernia. The direct sac is transposed into the indirect sac. (Hoguet.)

plete indirect hernia of the congenital type the sac is cut across near its mid portion and separated from the cord. The proximal end is closed by the method used above, and the distal end may be left in place.

If the indirect hernia emerges through a large internal ring (more than 2 cm.), a reconstruction of the posterior inguinal wall is necessary. The fascia is tightened

sac, thus converting the two sacs into one (Fig. 509). Similarly a femoral sac can be converted into an indirect sac. The direct sac is seldom opened, as transposition is all that is necessary.

It is necessary at this time to determine also the size of the internal ring and *to decide whether reconstruction of the posterior inguinal wall is* necessary. The opening in the end of the sac is enlarged so that any omental or bowel adhesions may be freed. If a sliding hernia is present, it should be handled according to the manner described later.

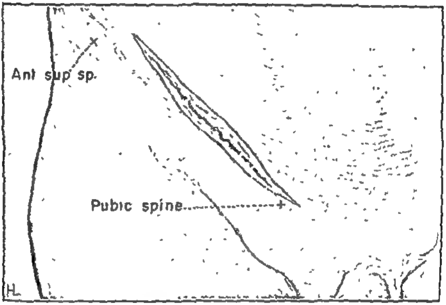


Fig. 506.—Inguinal herniorrhaphy. The skin incision.

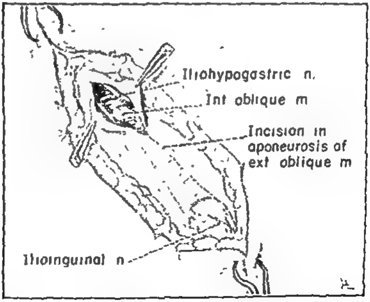


Fig. 507.—Inguinal herniorrhaphy. Incision in the aponeurosis of the external oblique muscle. Side sheets are used routinely but will be omitted from subsequent illustrations.

The indirect sac is closed as high as possible to prevent indirect recurrences (Fig. 510). The sac is transfixed by a doubled 000 silk suture which is tied on both sides of the sac and the sac is cut away (Fig. 511). The ends of the silk ligature are left long and are passed through the internal oblique muscle from behind forward

a short distance above the lower border of this muscle and slightly apart. The needle is passed eye first so as to avoid injury to any blood vessel within the muscle (Fig. 512). The two sutures are tied anterior to the muscle, thus anchoring the neck of the sac to the posterior surface of the internal oblique muscle. In cases of com-

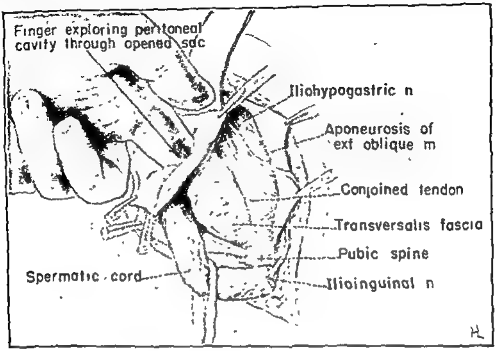


Fig. 508.—Inguinal herniorrhaphy. Finger inserted through opened indirect sac to explore for possible direct or femoral sac.

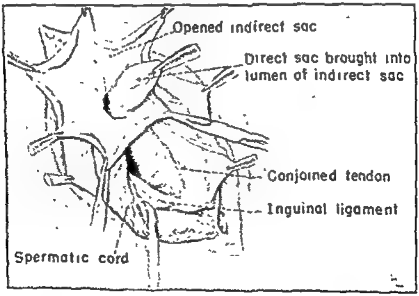


Fig. 509.—Inguinal herniorrhaphy. Combined direct-indirect hernia. The direct sac is transposed into the indirect sac. (Hoguet.)

plete indirect hernia of the congenital type the sac is cut across near its mid portion and separated from the cord. The proximal end is closed by the method used above, and the distal end may be left in place.

If the indirect hernia emerges through a large internal ring (more than 2 cm.), a reconstruction of the posterior inguinal wall is necessary. The fascia is tightened

above and medial to the ring by a partial purse-string suture of medium silk. This suture is never allowed to encircle the cord, and should never include any of the fibers of Poupart's ligament or the sphincter action of the internal ring may be partially destroyed. If the structures of the wall are good and if the internal ring is less than 2 cm. in diameter, a high ligation of the sac is essentially all that is necessary, since there is no anatomical defect other than the presence of a sac and

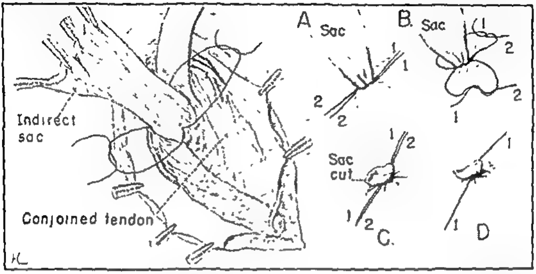


Fig. 510.—Inguinal herniorrhaphy. High ligation of neck of sac by double silk suture The insets show method of ligation One suture of each pair is left long for transfixing the sac.

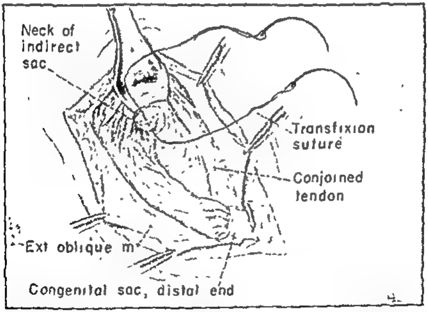


Fig. 511 —Inguinal herniorrhaphy Congenital sac The distal part of the sac is allowed to fall back into the scrotum The transfixing sutures are shown.

a slight dilatation of the internal ring. In addition, however, it is best to close the internal ring medial to the cord by suturing the transversalis fascia to the anterior layer of the femoral sheath under Poupart's ligament. An additional suture transfixes the fascia of the cord to the transversalis fascia (Fig. 513.) These sutures begin and end in the transversalis fascia, going first through the fascia, picking up either the inguinal ring or the cord, and then running back up through the trans-

versalis fascia so that the two ends are tied outside the internal ring. A modified Ferguson operation, as described later, may be used in place of this closure of the internal ring.

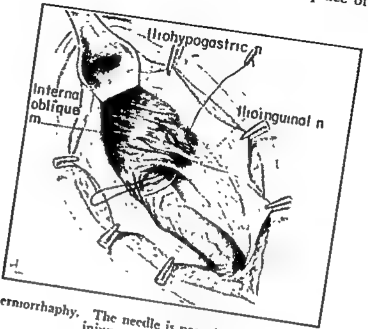


Fig. 512.—Inguinal herniorrhaphy. The needle is passed eye first through the muscle to avoid injury to blood vessels.

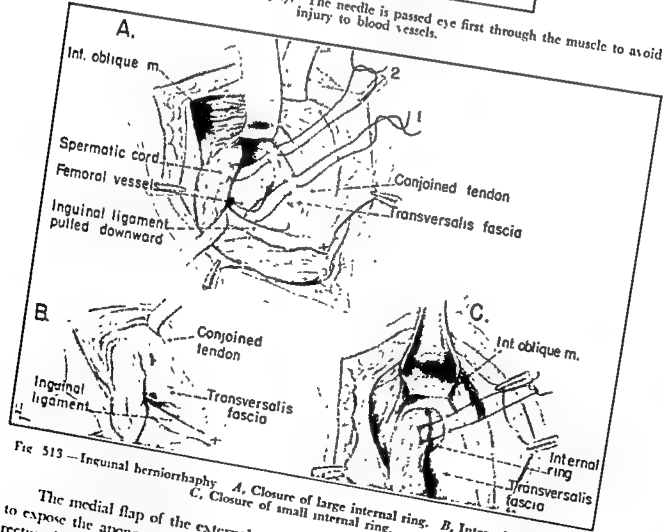


Fig. 513.—Inguinal herniorrhaphy. A, Closure of large internal ring. B, Internal ring closed. C, Closure of small internal ring.

The medial flap of the external oblique aponeurosis is then retracted medially to expose the aponeurosis of the internal oblique. The inner layer of the anterior rectus sheath is incised from a point 2 cm. above the pubic spine upward and

laterally for about 7 cm. (Fig. 514). This incision ends at the lateral border of the rectus abdominis muscle. Care is taken to prevent injury to the iliohypogastric nerve as well as to the small nerves and vessels that pass through the aponeurosis of the internal oblique to the rectus muscle. This relaxing incision will allow the sheath to slide laterally and downward and permit suture to Cooper's ligament without tension

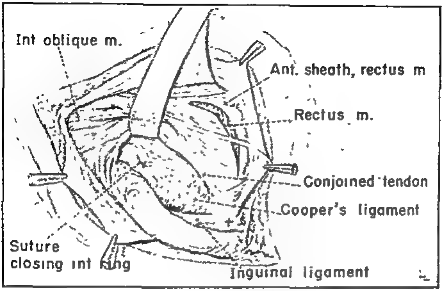


Fig 514 —Inguinal herniorrhaphy The incision in anterior rectus sheath relaxing the internal oblique muscle is shown.

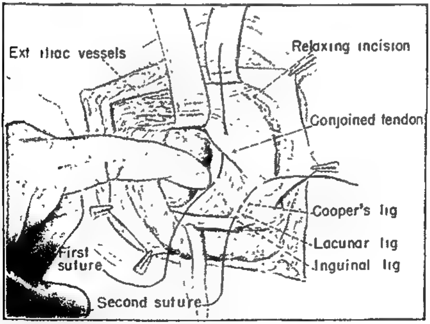


Fig. 515 —Cooper's ligament herniorrhaphy. The first and second sutures between the conjoined tendon and Cooper's ligament are in place.

Cooper's ligament should be fully exposed by separating the fascia over the anterior ramus of the pubis. The left index finger is moved along the anterior ramus from the pubic spine laterally until the femoral vessels are reached and identified. The vessels are thus held laterally with the finger while the first stitch is placed medial to the tip of the finger, some 3 to 4 cm. lateral to the pubic spine (Fig. 515). It is preferable to use 00 silk for these sutures and they should be

inserted through the conjoined tendon first and then through Cooper's ligament, the cord being retracted inferiorly and laterally all the while. This first suture is not tied for the present, and the second suture and ensuing ones are inserted from the medial end laterally to meet the first suture. The most medial sutures usually go through Gimbernat's ligament as well as Cooper's ligament. After all the sutures are inserted, the most medial one is tied first. This suture is brought down

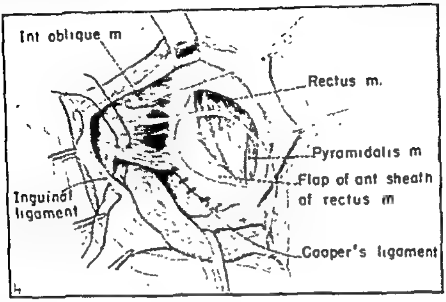


Fig. 516.—Cooper's ligament herniorrhaphy. The conjoined tendon is firmly sutured to Cooper's ligament, causing the rectus sheath incision to gape open The sutures lateral to the cord are in place.

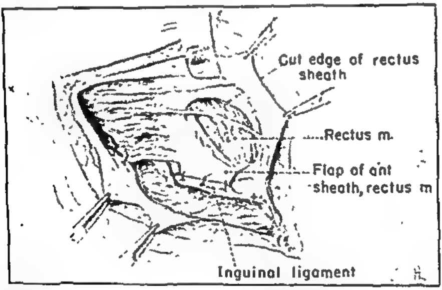


Fig. 517.—Cooper's ligament herniorrhaphy. The sutures lateral to the cord are tied. The flap in the rectus sheath is sutured to the inguinal ligament. The cord lies in this closure.

snugly and then the others are tied in order. The finger again holds the femoral vessels out of the way as the most lateral suture is tied. It is important that the most lateral suture be inserted first as it is easier to protect the femoral vessels at this time. It should not be tied until last, however, as otherwise the other sutures could not be inserted under direct vision.

The conjoined tendon, lateral to the most lateral Cooper's ligament stitch, is approximated to Poupart's ligament by interrupted medium silk sutures, to fit

laterally for about 7 cm. (Fig. 514). This incision ends at the lateral border of rectus abdominis muscle. Care is taken to prevent injury to the iliohypog nerve as well as to the small nerves and vessels that pass through the aponeuro *the internal oblique to the rectus muscle.* This relaxing incision will allow sheath to slide laterally and downward and permit suture to Cooper's liga without tension.

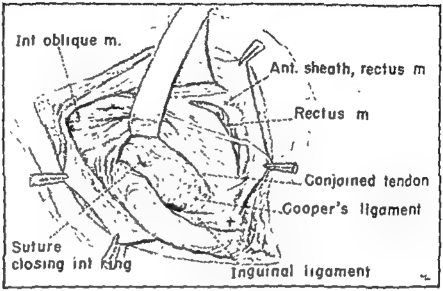
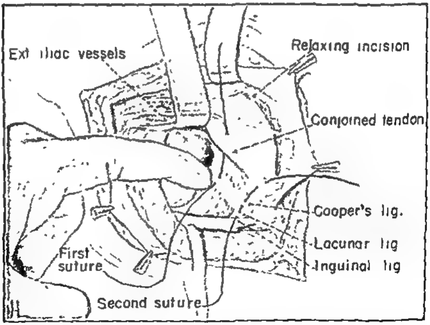


Fig. 514—Inguinal herniorrhaphy The incision in anterior rectus sheath relaxing the int oblique muscle is shown



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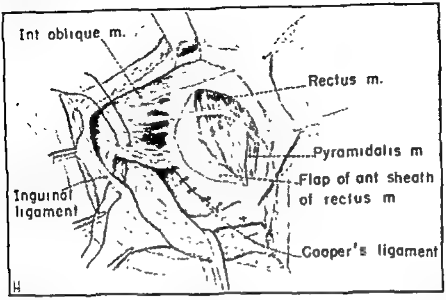

Fig 516.—Cooper's ligament herniorrhaphy. The conjoined tendon is firmly sutured to Cooper's ligament, causing the rectus sheath incision to gape open. The sutures lateral to the cord are in place.

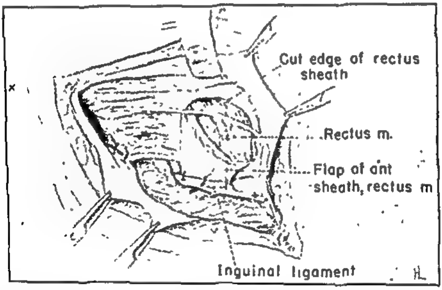

Fig 517—Cooper's ligament herniorrhaphy. The sutures lateral to the cord are tied. The flap in the rectus sheath is sutured to the inguinal ligament. The cord lies in this closure.

snugly and then the others are tied in order. The finger again holds the femoral vessels out of the way as the most lateral suture is tied. It is important that the most lateral suture be inserted first as it is easier to protect the femoral vessels at this time. It should not be tied until last, however, as otherwise the other sutures could not be inserted under direct vision.

The conjoined tendon, lateral to the most lateral Cooper's ligament stitch, is approximated to Poupart's ligament by interrupted medium silk sutures, to fit

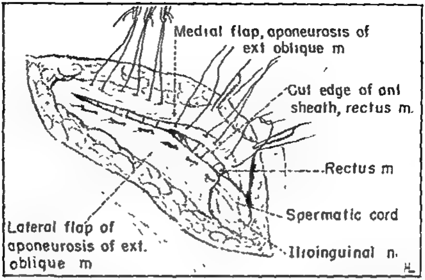

Fig 518 —Cooper's ligament herniorrhaphy Closure of the aponeurosis of the external oblique muscle The lateral flap is sutured to the medial cut edge of the rectus sheath.

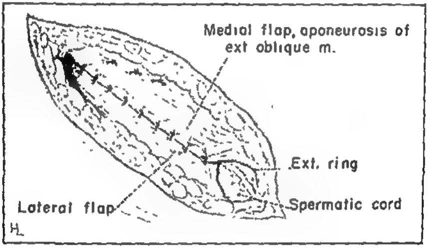

Fig 519 —Inguinal herniorrhaphy. Completed closure of aponeurosis of external oblique muscle.

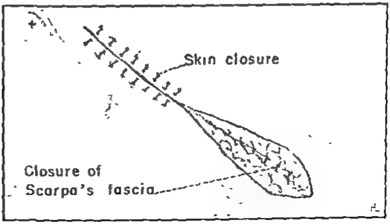

Fig 520 —Inguinal herniorrhaphy Closure of Scarpa's fascia and skin.

snugly about the upper end of the cord (Fig. 516). These sutures are not placed under any tension, and hence it is not felt that they pull the transversalis fascia away from Cooper's ligament. In fact, one recurrence through this defect when it was not closed has been noted.

An alternate closure of the fascia lateral to the femoral vessels is to suture the lateral portion of the transversalis fascia to the anterior layer of the femoral sheath far enough laterally to make a snug internal ring.

If there has been an unusually large flap made in the anterior rectus sheath, this flap can be turned down and anchored to the medial end of Poupart's ligament in a manner similar to the one Halsted first advocated (Fig. 517). If, however, the flap has been partially consumed by the suturing to Cooper's ligament, this procedure is omitted.

The cord is then allowed to fall in place on this new closure, the ilioinguinal nerve is released, and the external oblique aponeurosis is closed over the cord. The lower end of the lateral flap is sutured to the cut edge of the anterior rectus sheath, leaving sufficient room for the cord to emerge, while the remainder of the lateral flap is imbricated under the medial flap with fine silk sutures (Fig. 518). This procedure corrects the defect which might develop along the lateral edge of the rectus muscle after the flap of anterior rectus sheath is turned down. The medial flap is then sutured over the lateral flap and the repair is finished (Fig. 519). Scarpa's fascia is approximated with fine silk and the skin is closed with interrupted end-on-end mattress sutures of fine silk (Fig. 520).

The above operation is also used for direct and femoral hernias. In either case if there is an associated indirect sac, however small, it is removed as described above. Ordinarily it is not necessary to open a direct sac if it is small and diffuse. However, if it is large or pedunculated, the sac should be opened, examined for incarcerated or adherent bowel, closed in the usual manner, and excised.

In femoral hernias the inguinal ligament should be freed by blunt dissection and retracted inferiorly to expose the femoral sheath and the fascia of the pectineus muscle. An incision is made in the transversalis fascia as close to Cooper's ligament as possible and is carried laterally to the internal ring. The femoral sac is pulled into the opening of this incision and will now resemble a direct sac. The sac is opened, explored, ligated, and excised. The repair is similar to that given above. Other methods of handling femoral hernias are described below.

Bassini Procedure

In this technic the skin incision begins lateral to the internal abdominal ring about 2.5 cm. above Poupart's ligament and extends downward parallel to the fibers of the external oblique aponeurosis to the external ring. It is between 8 and 10 cm. in length. The external oblique aponeurosis is exposed and incised in line with its fibers, care being taken not to injure the iliohypogastric and ilioinguinal nerves. The aponeurosis is dissected up on each side, laterally and below to expose the inguinal ligament, and medially and above to show the outer border of the rectus sheath and the conjoined tendon. The cremasteric fascia is incised longitudinally and the rest of the cord is carefully separated from it throughout its extent in the inguinal canal. In an indirect hernia the sac is drawn upward and separated from the vas and the vessels of the cord as high as the internal ring. It is then opened, transfixed, ligated, and excised. If it is sufficiently freed from the sur-

rounding structures, the neck of the sac will retract well up under the border of the internal oblique muscle. When the sac is continuous with the tunica vaginalis, as in the so-called congenital type of hernia, it is divided in the middle and the lower part may be dissected out or allowed to fall back into the scrotum as already described. The conjoined tendon and internal oblique muscle are sutured to Poupart's ligament beneath the spermatic cord from the pubis to the internal ring, which should be narrowed until it fits the cord snugly but not tightly (Fig. 521). If the conjoined tendon contains considerable fascia, the fascial part can be sutured to Poupart's ligament with small bites of fine silk. If, however, the conjoined tendon is mostly muscle, and since the healing of muscle to fascia is accomplished only between the fibrous coverings of the muscle and the connective tissue of the fascia, it is necessary to take wide bites of both the muscle and the fascia of Poupart's ligament to approximate wide surfaces of each.

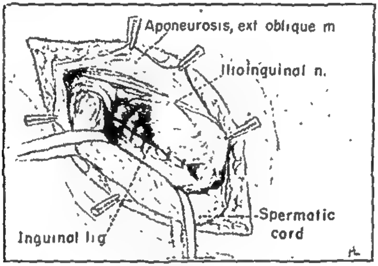

Fig 521.—Inguinal herniorrhaphy. Bassini technic. The conjoined tendon is sutured to inguinal ligament under the cord.

Halsted Procedure

In Halsted's original operation the internal oblique muscle was divided up to the internal ring, and the cord, which was decreased in size by excising some of its veins, was then allowed to pass out through the thicker portion of the muscle which was sutured below it. The cord was also brought out through the aponeurosis of the external oblique, which was approximated under the cord, thus placing it immediately beneath the skin and subcutaneous tissue. It was found, however, that a considerable number of patients developed atrophy of the testicle following this procedure, so excision of the veins was discontinued. Division of the internal oblique muscle was next given up, and finally it was decided to leave the cord in its normal position Up to the closure of the external oblique aponeurosis the technic was similar to Bassini's operation.

Torek Procedure

Torek believed that indirect inguinal hernia developed as a result of the separation of the vas and vessels of the cord at the internal ring, since this causes a dimpling of the peritoneum in this area. He, therefore, advised in transplanting the cord that the vas be separated from the vessels, and that the internal oblique muscle be sutured to Poupart's ligament between these structures.

Ferguson Procedure

Ferguson advocated careful suture of the transversalis fascia, then suture of the conjoined tendon and muscle to Poupart's ligament anterior to the cord. In a modification of this procedure, the same incision already described is used as well as the same handling of the sac. The transversalis fascia is inspected, and, if it is thinned out near the internal ring, it is fastened to Poupart's ligament with interrupted sutures of fine silk, leaving only enough room for the cord to pass through. The internal oblique muscle and the conjoined tendon are sutured to Poupart's ligament anterior to the cord from a short distance above the level of the internal ring down to the pubis with interrupted sutures of medium silk. Sufficient room is left below to admit the tip of the index finger, so that the cord would not be constricted. (Fig. 522.) If the conjoined tendon is unusually weak, a section of the anterior sheath of the rectus muscle is reflected outward and sutured to Poupart's ligament at this point. The aponeurosis of the external oblique is imbricated as described above.

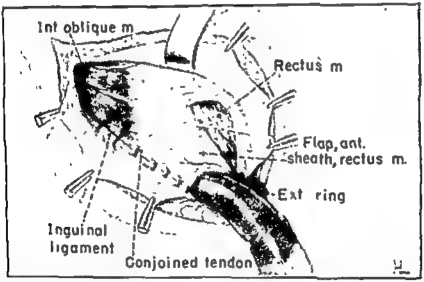

Fig. 522.—Inguinal herniorrhaphy. Ferguson technic. The conjoined tendon is sutured to the inguinal ligament over the cord. The external ring admits only the tip of the index finger. A rectus sheath flap is turned down in this type of repair and sutured to the medial end of the inguinal ligament.

Andrews Procedure

In the Andrews operation the posterior inguinal wall is strengthened by suturing and tightening the transversalis fascia. The conjoined tendon and the medial flap of the external oblique aponeurosis are then sutured to the inguinal ligament and the lateral flap of the aponeurosis is sutured over the cord to the anterior surface of the medial flap. This is the Andrews imbrication operation.

Special Procedures

In hernias having a deficient conjoined tendon it is sometimes impossible to close the inguinal canal without too much tension. It is in this type of hernia that the Bassini operation was formerly employed since there was not sufficient room in the canal to allow the cord to remain in place Because of failures to close the floor of the canal, even with the Bassini operation, many special technics have been advised, some of which have considerable merit.

fascia lata, and this had the advantage of an unlimited source of supply. The fascial strip or strips were woven back and forth across the defect between the conjoined tendon and Poupart's ligament to obliterate this space, and were tightened only enough to flatten them out (Fig. 524, *A*).

Tantalum Mesh

Largely because of the experimental and clinical work of Koontz, tantalum *mesh seems to be superior to fascia or skin grafts in repairing* weakened posterior inguinal walls. The metal is well tolerated and produces no unfavorable reactions. It soon becomes covered and infiltrated with dense fibrous tissue. It has been used on ventral hernias as well as inguinal hernias with apparently excellent results. It is used only on the inguinal hernias in which poor tissues and large defects are present, and is used to reinforce Hesselbach's triangle after a Cooper's ligament repair has been done, including a relaxing incision in the anterior rectus sheath.

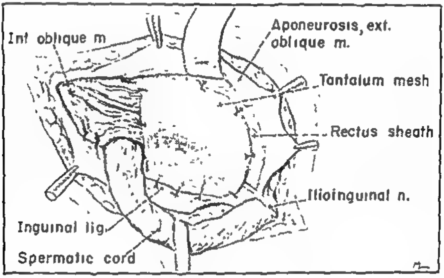

Fig. 525.—Inguinal herniorrhaphy Insertion of tantalum mesh gauze under the cord.

A piece of tantalum mesh large enough to cover the area of Hesselbach's triangle is laid on the first suture line. The lower edge of the mesh is turned over on itself and sutured to Poupart's ligament. The mesh is then inserted into the depression over the suture line and a suture is placed deep in this depression, anchoring the mesh to the muscle below A few sutures are placed in the other edges of the mesh which have not been turned under. Only a few sutures are needed to hold the mesh in place, and fine silk is used throughout. (Fig. 525) Koontz places a piece of Gelfoam in the depression over the mesh, believing that the interstices of the Gelfoam will become filled with serum and fibrin, which in turn will be converted into fibrous tissue. The aponeurosis of the external oblique is closed without imbrication and the cord is allowed to drop on the aponeurosis. It is wise to insert a small drain through a stab wound near the site of the mesh, particularly if a large piece is used. This is particularly true in ventral or incisional hernias, although the use of Gelfoam may make drainage unnecessary

Inguinal Hernia in Infants and Children

The surgical treatment of inguinal hernia in infants and children should consist of complete excision of the sac and nothing more. This operation should be

performed as soon as the condition is diagnosed, regardless of age, except in the case of newborn infants, who should be allowed to regain their birth weight before being subjected to an operation. After four years of experience in the above procedure, there have been no recurrences or adverse result.

The majority of surgeons in this country still do some form of muscle repair in children who are operated upon for inguinal hernia, believing that the repair does no harm and that it closes an alleged weakness at the internal ring. However, there seems to be a definite trend away from doing any form of herniorrhaphy, and it is thought that a simple sac removal will soon be the universal procedure.

The literature varies considerably as to the type of muscle repair that should be done. Iason recommends two to three chromic catgut sutures to approximate the conjoined tendon to Poupart's ligament but admits that they are not essential. Larsen advises the Ferguson repair; whereas Schiebel and Freeman use either a Halsted, Bassini, or a Ferguson repair, all with good results. It becomes obvious that the results will be good, since all of these surgeons include complete excision of the sac as part of the operation. Potts has done simple sac removal for twelve years and has presented the largest series of cases thus treated.

Hernias in infants and children are almost invariably indirect. The indirect hernia is not due to muscle weakness but to a failure of the processus vaginalis to obliterate itself, thus leaving an open sac. Straining, coughing, crying, and normal childhood activity may suddenly cause the development of the hernia, with or without symptoms. The diagnosis is relatively easy when the hernia is visible and palpable, but unfortunately the hernia is not always seen by the examiner. The mother's history and description of the bulge will usually be reliable, and a hernia will invariably be found if one is willing to operate on these terms.

Incarceration is a real danger in infants and will be found in roughly 25 per cent of the cases. The bowel as well as the testicle can be damaged by incarceration, and thus incarcerated hernias should be operated upon as emergency procedures. No attempt should be made to reduce the hernia before operation. If the hernias are bilateral, they are both removed at one operation, using two separate incisions. Hydroceles are common in children and are almost invariably associated with a hernia, however small. Larsen feels that compressible hydroceles are communicating hydroceles and are always infantile hernias, whereas noncompressible hydroceles are noncommunicating hydroceles and most of them are associated with a definite hernia. The hernia sac is always looked for, and if found it is removed. The available portion of a hydrocele sac may be removed, but no plastic repair around the testicle or cord is necessary.

Although some clinics recommend the use of local anesthesia, with or without the sugar-whisky pacifier, for hernia operations in infants and children, general anesthesia seems preferable unless there is a definite contraindication to its use. The child is admitted to the hospital the night before operation, and the surgery is performed early the following morning. It does not seem proper or wise to delay the operation until late morning or afternoon, as the children are hungry, fretful, and at times scared It is best to operate as soon after they awaken as possible.

No attempt is made to restrain the child after operation, and they are allowed to go home the following day. No restriction is made on their activity, as the mild postoperative soreness will provide the only necessary restraint. The parents, as

well as the child, are much happier with this arrangement. Five-tenths cubic centimeter (150,000 units) of the long-acting procaine penicillin is given before the child awakens from the anesthetic and repeated the following morning just before discharge from the hospital.

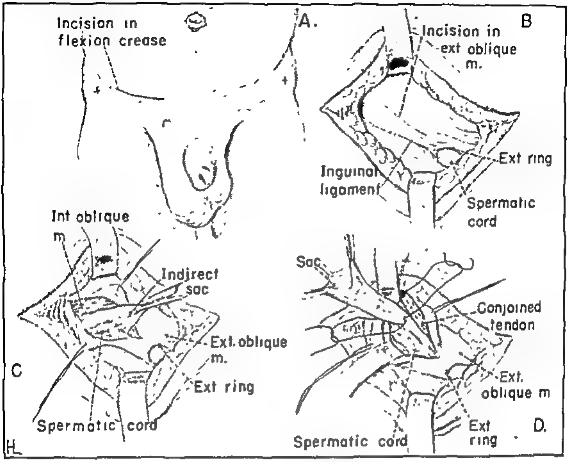

Fig 526 —Inguinal herniorrhaphy in infants. *A*, Skin incision. *B*, Incision in aponeurosis of external oblique muscle. The external ring is not opened. *C*, Isolation of sac. *D*, High ligation of sac.

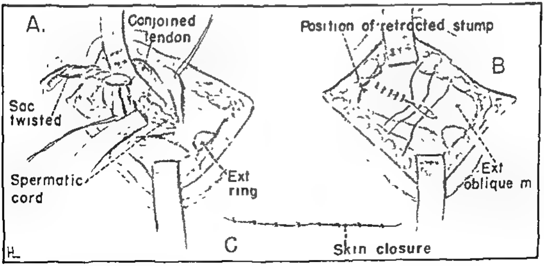

Fig 527 —Inguinal herniorrhaphy in infants. *A*, Method of twisting a thin sac. The sac is then transfixed and ligated (Potts) *B*, Closure of aponeurosis Note position of retracted sac. *C*, The skin incision is closed with catgut and covered with collodion gauze.

Method of Repair.—The skin of the lower abdomen, penis, and scrotum is prepared for the operation. A transverse incision is made in the lower flexion crease of the child's abdomen from 1 to 2 cm. medial to the anterior-superior spine to roughly the lateral edge of the rectus muscle (Fig. 526, *A*). This incision will be approximately 2.5 cm. long in infants and slightly longer in children, and it is preferable to the usual oblique incision in that it follows the lines of cleavage, is easier to close, is less apt to become infected, and leaves a scarcely visible scar. The subcutaneous fat, which is considerable in infants, is divided along the course of the incision, and bleeding is carefully controlled. The lower part of the incision is retracted downward to expose the external ring. The external oblique aponeurosis is divided parallel to its fibers, but the incision should not necessarily open the external ring (Fig. 526, *B*). The lower flap of the aponeurosis is retracted downward to expose the cord. The cremasteric fibers are separated with a hemostat and the sac is easily identified by its white color. It is grasped and lifted up and away from the cord

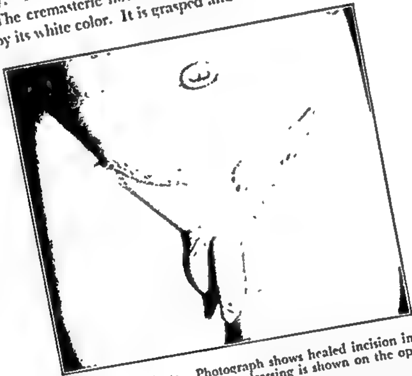

Fig 528—Inguinal hernia in infants. Photograph shows healed incision in lower flexor crease of the abdomen The collodion gauze dressing is shown on the opposite side.

(Fig 526, *C*). The sac is opened and inspected for the presence of intestines or omentum. With steady traction the sac is gently freed away from the vas deferens and vessels of the cord. The cord is otherwise left unmolested. The sac is freed as high as possible and the neck is ligated with a double suture ligature of silk which is tied on both sides (Fig. 526, *D*). The excess sac is then removed and the neck is allowed to retract up under the internal oblique muscle. In infants the sac is often thin and friable. Potts wisely advises that these thin sacs, after inspection of their interior, should be twisted until the preperitoneal fat appears or until the neck of the sac is obliterated, and then the sac is transfixed at the neck with a suture ligature (Fig. 527, *A*). In true congenital hernias where the testicle is in the lower end of the sac, the sac may be divided in its mid portion and the distal end allowed to fall back into the scrotum It is unnecessary to perform an associated bottle operation. The opening in the external oblique aponeurosis is closed with interrupted sutures of fine silk, and, since the external ring is usually not opened, there is no danger of closing it too tightly and causing constriction on the vessels of the cord (Fig. 527, *B*).

The superficial fascia and subcutaneous fat are approximated with fine silk and the skin is closed with a continuous suture of fine five 0 plain catgut (Fig. 527, *C*). The use of catgut gives a fine clean closure and there are no sutures to be removed later. The incision is covered with flexible collodion which is allowed to dry and then is itself covered with a small strip of gauze impregnated with collodion (Fig. 528). When this gauze comes loose of its own accord, usually in five to seven days, the sutures have usually disappeared and the wound is well healed.

Sliding Hernia

Sliding hernias are always difficult to repair, for, since a viscus actually forms a portion of the wall of the sac, high ligation and excision of the sac are impossible (Fig. 529). The diagnosis of sliding hernia is often not made until the sac is

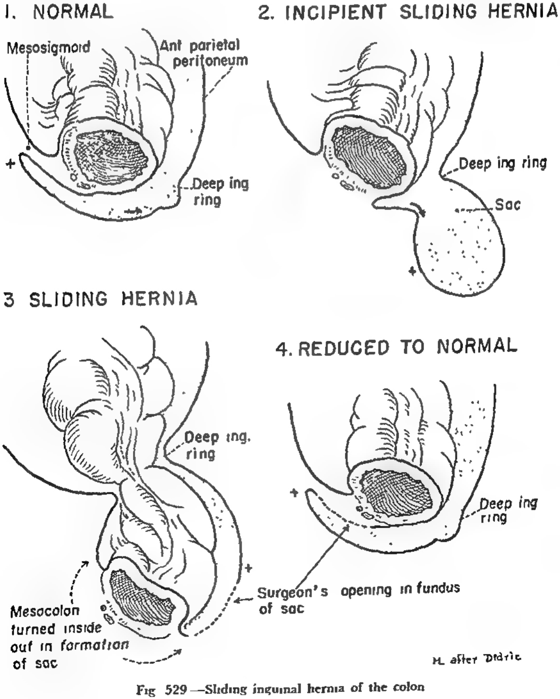

Fig 529.—Sliding inguinal hernia of the colon

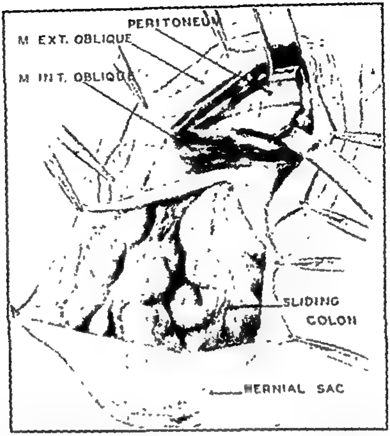

Fig. 530.—Sliding inguinal hernia. The sac is open. The muscle-splitting incision is retracted to show location of the peritoneal incision. (Courtesy C. Williams, Ann. Surg. 126: 612, 1947.)

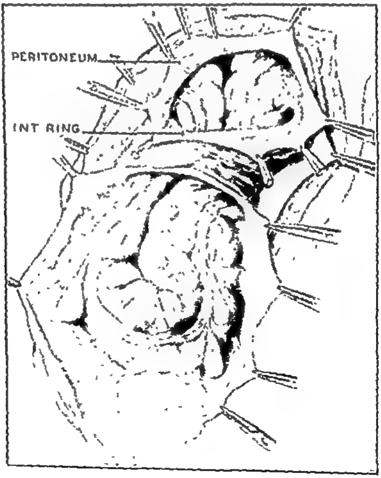

Fig 531.—Sliding inguinal hernia. Peritoneum open showing sigmoid colon entering the internal ring. (Williams.)

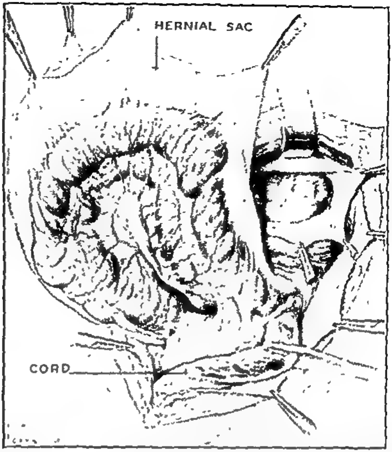

Fig. 532.—Sliding inguinal hernia. The sac and sigmoid colon have been dissected from the cord and lifted, showing the posterior surface of the colon and its blood supply. (Williams.)

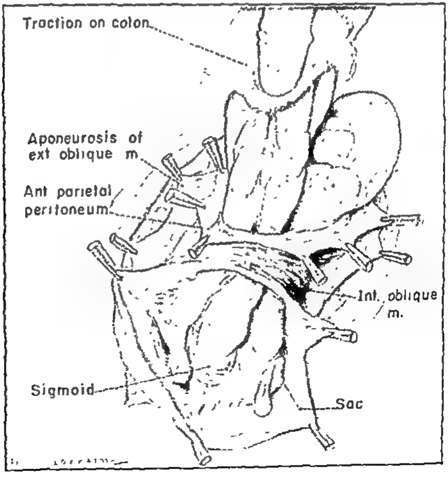

Fig. 533.—Sliding inguinal hernia. Traction on the colon through the upper incision draws the colon and the sac into the peritoneal cavity.

opened at operation, but it should be suspected in an indirect hernia which has a large internal ring and is difficult or impossible to reduce completely. The hernia may be repaired through an inguinal or abdominal approach, depending chiefly on the size of the hernia.

In the operation described by Bevan the approach is similar to that used in uncomplicated inguinal hernia. The incision into the sac is made with unusual care to avoid injury to the viscus which forms its posterior wall. When either the sigmoid or the cecum is involved, Bevan incised the avascular outer fold of the mesocolon, for the blood supply to the bowel comes through the mesial fold. With care to avoid injury to its blood supply, the bowel is then separated from the posterior wall. Before returning the bowel to the abdomen, Bevan sutured the peritoneal edges over the raw surface on the posterior bowel wall. He then inserted

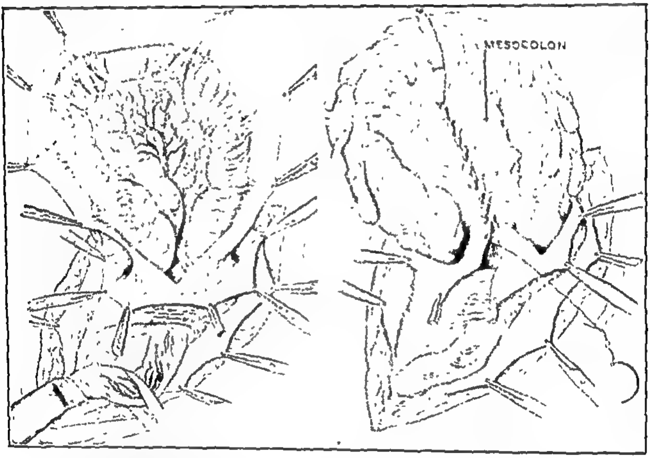

Fig. 534. Fig. 535.

Fig. 534.—Sliding inguinal hernia. The colon and the sac have been delivered into the upper wound. (Williams.)

Fig. 535.—Sliding inguinal hernia. The excess peritoneum of the sac has been removed and the lateral leaf of the mesocolon is reconstructed. (Williams.)

a series of three or four purse-string sutures in the sac, the first, or inner one, as high as possible. The sac is thus partially inverted and the outer suture is tied. This is carried out with each of the purse-string sutures until the entire sac is inverted Closure is made as in direct hernia.

The technic suggested by Moschowitz and recommended by Graham is a safe and satisfactory way to treat sliding hernias. Moschowitz entered the free peritoneal cavity above the internal ring, either by separating the fibers of the internal

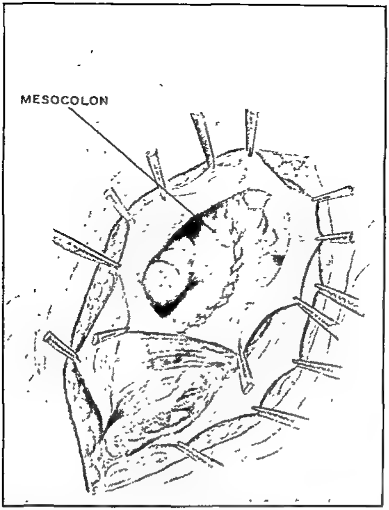

Fig. 536 —Sliding inguinal hernia The sigmoid colon has been restored to the abdominal cavity. Not how the suture line in the mesocolon extends into the peritoneum of the abdominal incision (Williams)

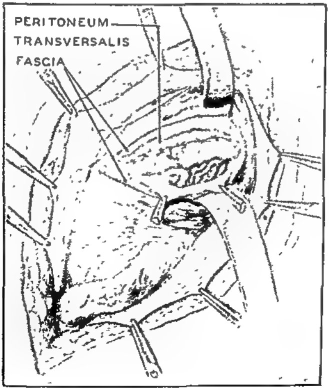

Fig. 537 —Sliding inguinal hernia. The peritoneum is closed. The transversalis fascia and the internal oblique muscle are closed next, and the inguinal canal is repaired. (Williams)

oblique muscle at the upper end of the extended hernia incision or, in very large hernias, through a mid-rectus incision. He then applied traction above the prolapsed bowel by grasping the ascending colon on the right side or the descending colon on the left, and thus completely reduced the hernia. When this is done, the incision in the anterior peritoneum of the sac becomes a mere slit, which may be closed by a few sutures. The segment of bowel is held in its normal position and attached to the posterior wall by sutures. This must be done with particular care on the medial side to avoid injury to the vessels or to the ureter. Graham reduced the hernia by the same maneuver but apparently considered fixation of the bowel to the posterior wall unnecessary.

Williams recently reemphasized the advantages of the La Roque approach for the repair of sliding hernias. The usual inguinal incision is made, and, after exposure of the sliding hernia through the opened sac, the internal oblique and transversus abdominis muscles are opened about 2 cm. above the internal ring, care being taken not to injure the iliohypogastric nerve. The muscles are retracted and the peritoneum is opened transversely (Fig. 530). The sac is completely dissected from the cord, and the colon, on the right or left side, is mobilized (Figs. 531 and 532). Traction on the colon from within the abdomen draws it and the sac into the peritoneal cavity (Fig. 533). The anterolateral wall of the sac is now seen to be the outer leaf of the mesocolon and is continuous with the lower lip of the upper opening into the peritoneal cavity (Fig. 534). The excess sac is cut away, the mesocolon is closed by suture, and the bowel is allowed to fall back into the peritoneal cavity (Figs. 535 and 536). The peritoneum is then closed, the suture line in the mesocolon running into its lower lip, and the internal oblique and transversus abdominis muscles are sutured (Fig. 537). The inguinal canal is now repaired. Williams uses a modified Bassini method, but the Cooper's ligament repair is advised in any large indirect hernia. The La Roque approach is one of the best ways to repair large sliding hernias. In small sliding hernias where the bowel is just entering the sac, the repair may be done through the inguinal incision by pushing up on the bowel and closing the sac as high as possible.

Groin Hernias in the Female

Inguinal hernia is the commonest type of hernia in the female. Femoral hernia is less common, but is seen more often in females than in males, and is frequently incarcerated. The repair of any of the various types of groin hernia is similar to that in males, but the problem is simplified by the presence of the round ligament instead of the spermatic cord. A complete closure of the inguinal canal can be made in inguinal hernias by the Ferguson technic, but many surgeons use the Cooper's ligament repair in females as well as males. The latter technic is employed in women only in the correction of femoral hernias, as it properly corrects the existing defect better than any other type of repair.

FEMORAL HERNIA

As already shown, a Cooper's ligament operation is adequate and preferable for repair of femoral hernias. There is still some controversy, nevertheless, as to whether femoral hernias should be repaired from above or below Poupart's ligament. In addition to the Cooper's ligament repair, therefore, the following is pertinent to the subject.

A femoral hernia passes through the femoral ring and then into the femoral canal which lies between the lacunar ligament and the femoral vein. In femoral hernia the femoral ring is enlarged medially at the expense of the insertion of the transversalis fascia into Cooper's ligament and is thus a narrowing of the insertion of this layer. The hernia descends through the femoral canal, then through the fossa ovalis and Scarpa's triangle and is recognized as a subcutaneous bulge, practically always, of necessity, inferior to Poupart's ligament. The incidence of incarceration with or without strangulation is high in femoral hernias. As a result, most femoral hernia repairs are done as soon as they are recognized. As stated, they may be approached from above or below Poupart's ligament. The subinguinal incision gives a more direct approach to the fundus of the sac and therefore may

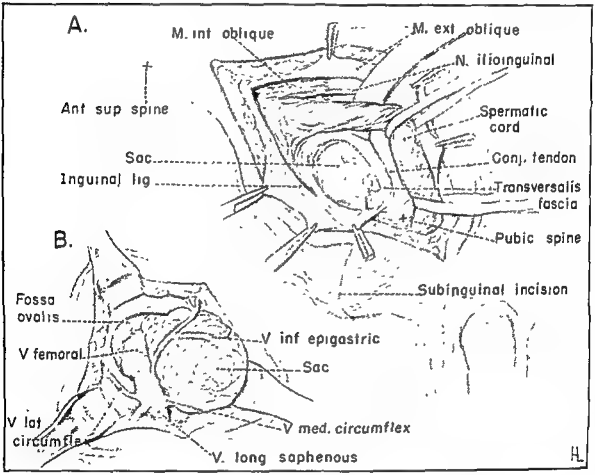

Fig 538 —Femoral hernia *A*, The inguinal incision is open. The transversalis fascia is incised showing the femoral sac The location of the subinguinal incision is shown, although this approach is not recommended *B*, The subinguinal incision is open, showing the fundus of the femoral sac and neighboring vessels

appear simpler (Fig. 538.) Unfortunately, it gives inadequate access to the neck of the sac and presents almost no opportunity for satisfactory repair of the femoral ring. The chances of recurrence are greatly increased, therefore, by the use of this approach. It is extremely difficult, if not dangerous, to reduce a strangulated loop from below as it may be impossible to do so without division of the inguinal or the lacunar ligament Division of the inguinal ligament is always undesirable, and blind division of the lacunar ligament is dangerous because of the frequent anomalous origin of the obturator artery from the deep epigastric, when it may pass down across the anterior and medial side of the femoral ring and perhaps be cut.

For these reasons the repair of femoral hernia should rarely be attempted by the subinguinal route. If, for any reason, this route is chosen, it is probably better to make a short perpendicular incision over the lower end of the femoral canal. The saphenous and femoral veins which lie in close proximity to the sac should be carefully exposed and protected. The sac is completely dissected out and the neck of the sac is separated from the walls of the canal as high as possible. The sac is opened and the contents, if any, are replaced into the peritoneal cavity. The neck is pulled downward as far as possible and the sac is ligated and excised. After removal of the sac, closure of the canal consists of approximating Poupart's ligament to the pectineus fascia. As stated above, this is almost impossible, as well as dangerous, so it is probably as well not to attempt it. In case of strangulation which cannot be reduced from below, or if it is decided to repair the ring, the skin incision may be extended upward across the inguinal ligament (which is not cut unless it is absolutely necessary), then upward and laterally parallel to this ligament, and the ring is thus exposed from above. If division of the inguinal ligament cannot be avoided, it may be satisfactorily repaired by the use of a flap from the aponeurosis of the external oblique muscle.

The approach to a femoral hernia from above the inguinal ligament is similar to the technic previously described for inguinal hernia. An alternative operation, which is also satisfactory, may be done. The inguinal canal is opened, the cord is retracted, and the posterior inguinal wall is incised just above its insertion into Cooper's ligament to uncover the upper end of the canal from within the abdomen. If the hernia is incarcerated, reduction can usually be accomplished by making gentle traction on the loop of bowel above, while pressing over the mass below Poupart's ligament, but occasionally it may be necessary to make a small incision on the medial side of the femoral ring through the edge of Gimbernat's ligament. In nonincarcerated hernias and after reduction in incarcerated hernias, the sac is delivered above Poupart's ligament and all of it, including the neck, is removed by an elliptical incision which is closed by a continuous suture. The femoral ring can be obliterated by suturing Poupart's ligament to Cooper's ligament with interrupted sutures of medium silk. These sutures are inserted first through Poupart's and then through Cooper's ligament; in other words, from before backward when operating on the right side, and in the reverse direction when the repair is being done on the left side. A Ferguson repair may then be done. By this approach the femoral canal can be readily closed from above with little danger of injury to the femoral vein or the deep epigastric artery, which crosses on the transversalis fascia a short distance above the femoral canal, or to the obturator artery, which, as stated, may arise from the deep epigastric artery and go across the anteromedial border of the ring.

UMBILICAL HERNIA

There are three types of umbilical hernia: (1) congenital hernia into the umbilical cord, (2) infantile umbilical hernia, and (3) adult umbilical hernia. The first two are congenital in origin and the latter is acquired, although there may be an associated congenital factor.

Hernia Into the Umbilical Cord

This type of hernia is due to a failure of the rectus abdominis muscle to become approximated in the midline. Varying portions of the abdominal viscera protrude

into the umbilical cord and are therefore covered only by the gelatinous amniotic layer of the cord (Fig. 539, *A*). This tissue is not covered by epithelium and rapidly becomes desiccated and necrotic, exposing the viscera to external contamination. Repair, therefore, should be attempted as soon as possible after birth.

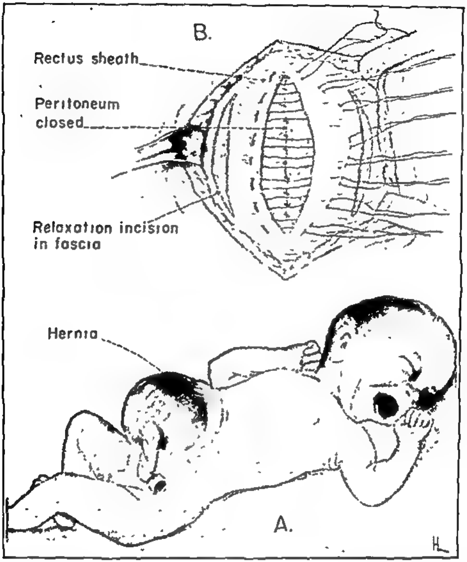

Fig. 539.—A, Congenital hernia into the umbilical cord. B, Method of closure. Relaxing incisions may be necessary to obtain closure of the fascia The peritoneum cannot always be closed.

Where only small bowel presents outside the abdominal wall, the closure is readily made, but, in very extensive defects where practically all of the abdominal viscera lie outside the abdominal cavity, repair is difficult or may even be impossible. To prevent a recurrence the fascia will have to be approximated, but, if the defect is so large that the fascia cannot be closed, the skin alone is sutured over the defect. Even though the skin itself seems inadequate, closure may often be accomplished by careful undermining of the skin and by relaxing incisions through the skin and fascia laterally (Fig. 539, *B*). The cord and a narrow margin of skin are excised and the rectus muscles are approximated in the midline. The skin must be separated from the fascia in all directions, and, if enough fascia is present, the peritoneum should be dissected free from the fascia on one side and this latter

flap imbricated over the flap of the opposite side, thus allowing fascia to be sutured to fascia. If the fascia will close, there will be no trouble in closing the skin. Fine silk or cotton sutures should be used.

Infantile Umbilical Hernia

If the defect in the fascia at the umbilicus does not close shortly after birth, normal straining will force the viscera against the ring and enlarge it, thus producing a small umbilical hernia. If the defect closes, but with improper support, a hernia may soon develop, usually within the first two years of life. In the very young, conservative measures may be employed. Any technic or device that will prevent herniation may allow the fascia to heal. If healing has not taken place by the end of the third year, however, the hernia will have to be repaired as described below, although a midline incision may be preferable in this type.

Adult Umbilical Hernia

This type of hernia is seen more commonly in women. Pregnancy, obesity, strain, and exertion are all factors in the etiology. Since conservative measures of treatment are unsatisfactory, except in very poor-risk patients, the treatment for this type of umbilical hernia is surgical, chiefly because of the high incidence of incarceration.

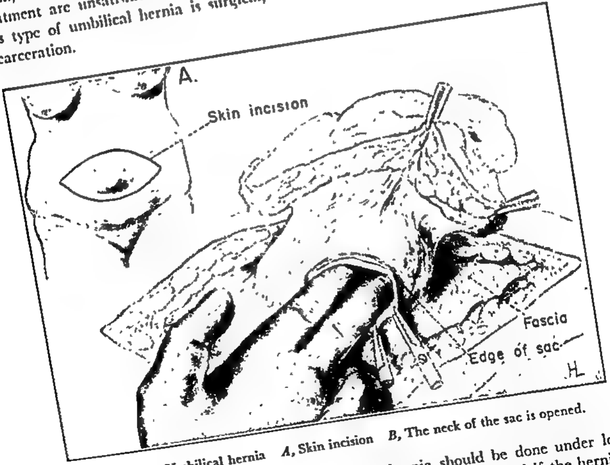

Fig 540.—Umbilical hernia *A*, Skin incision *B*, The neck of the sac is opened.

The operation for strangulated umbilical hernia should be done under local anesthesia. In nonstrangulated cases, local anesthesia may be used if the hernia is small, but if the ring is large, the relaxation obtained by spinal anesthesia or Pentothal Sodium and curare is of great help in its closure.

The umbilicus is excised by transverse elliptical incisions. Ramifications of th sac may project subcutaneously beyond the limits of the skin incision, and car must be used in making the incisions so as not to injure the contents of the sac In incarcerated hernias it is best to dissect directly down to the sac, which is opene

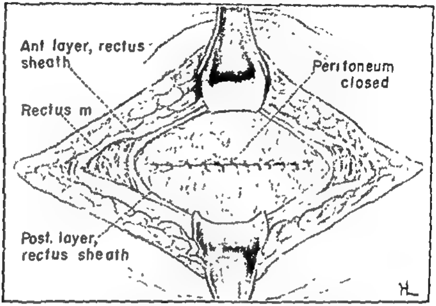

Fig. 541.—Umbilical hernia. The peritoneum is closed transversely and the ring is enlarged b incision of the rectus sheath on each side.

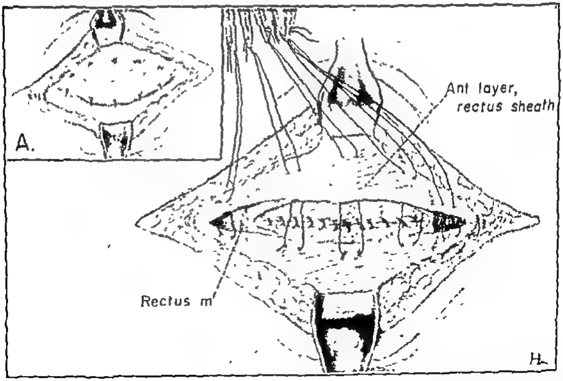

Fig 542—Umbilical hernia Mayo closure by imbricating upper flap over lower flap. Actu ally the sutures are placed much closer together Inset shows completed closure.

and the contents inspected before making an extensive dissection to expose the anterior sheaths of the rectus muscles. If it is found that gangrenous or perforated bowel is present, the bowel should be resected and the ring closed with a few inter-

When the contents of the sac are omentum or bowel in good condition, the superficial tissues should be dissected from the sheaths of the recti for a considerable distance on all sides of the hernia ring before attempt is made to deal with the sac. After this is done, if the bowel and omentum are adherent to the sac, the sac is incised near the margin of the fascial ring, everted, and the structures are freed from the peritoneum under direct vision and replaced in the abdomen (Fig. 540). The entire sac is then excised. When the omentum alone is incarcerated in the sac, it may be ligated in segments and resected rather than removed from the sac. This saves time and decreases the amount of tissue that must be replaced within the abdomen.

The ring is enlarged by short transverse incisions on each side and closed by the Mayo method of overlapping the flaps of peritoneum and fascia in a transverse direction. The peritoneum is closed with chromic catgut (Fig. 541), but interrupted silk, cotton, or stainless steel wire sutures are used for the fascia. The inferior flap of fascia is drawn up beneath the superior flap by inserting sutures through the upper flap from without inward at a distance of 2 to 4 cm. from its lower margin, depending on the size of the flap. The suture then passes to the lower flap, taking a small bite near the upper border, and returns to pierce the upper flap from within outward so as to emerge about 0.5 cm. from the point of entry. A series of such sutures is placed across the defect before any one of them is tied. By doing this, somewhat finer suture material may be used, for when one suture is being tied, tension is relieved by traction on the others. The dependent edge of the upper flap is then sutured to the outer surface of the lower flap, care being taken not to enter the peritoneal cavity (Fig. 542). The superficial tissues are approximated with fine plain catgut or silk, and the skin with interrupted on-end mattress sutures of fine silk. If the patient is obese and a considerable amount of dissection trauma has been necessary, a small drain may be inserted down to the fascia for about twenty-four hours to prevent collections of serum.

INCISIONAL HERNIA

Incisional or ventral hernia is a late complication of abdominal surgery. It is usually due to a disruption of the fascial layers of a wound followed by a herniation of the peritoneum. This disruption may take place in the early postoperative period, and, unless evisceration occurs, it may go unrecognized. The type of operation indicated in incisional hernia depends on the location and size of the hernia. Small incisional hernias, especially those which follow drainage through a muscle-splitting incision, are best treated by dissecting out the component parts of the abdominal wall and closing them in layers. Large incisional hernias, especially those in or near the midline, should be closed by overlapping the fascial flaps in a manner similar to that used in the Mayo operation for umbilical hernia, except that the overlapping should usually be done from side to side.

Practically without exception the original scar is excised in making the new incision (Fig. 543). The incision is carried through the subcutaneous tissue down to the fascia, care being taken not to injure any of the ramifications or pockets of the sac that may have projected under the incision for varying distances. The sac is freed entirely from the surrounding adipose tissue by both blunt and sharp dissection. Careful attention to hemostasis is important. As in umbilical hernia, if strangulation is present it is best to open the sac before making a wide exposure of

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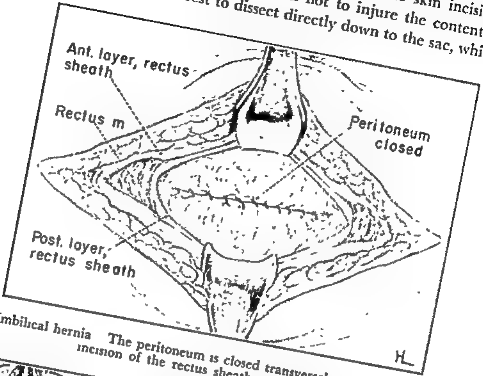

Fig. 541 —Umbilical hernia The peritoneum is closed transversely and the ring is enlarged by incision of the rectus sheath on each side.

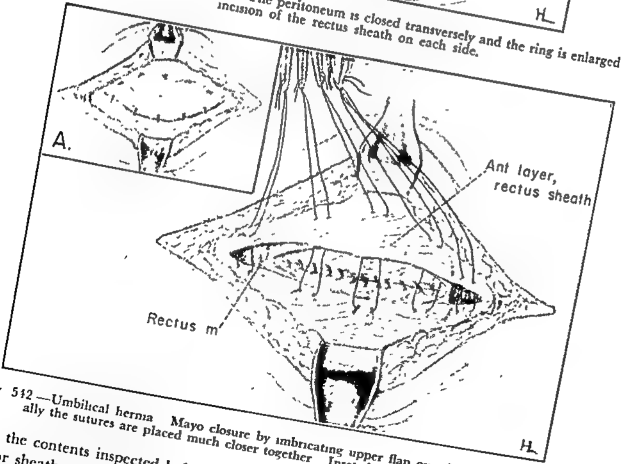

Fig 542 —Umbilical hernia Mayo closure by imbricating upper flap over lower flap Actually the sutures are placed much closer together Inset shows completed closure

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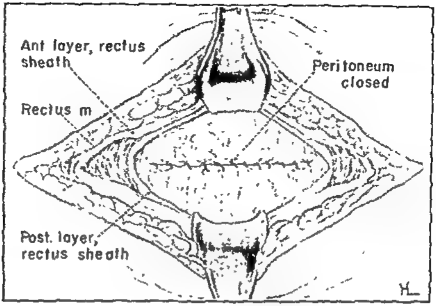

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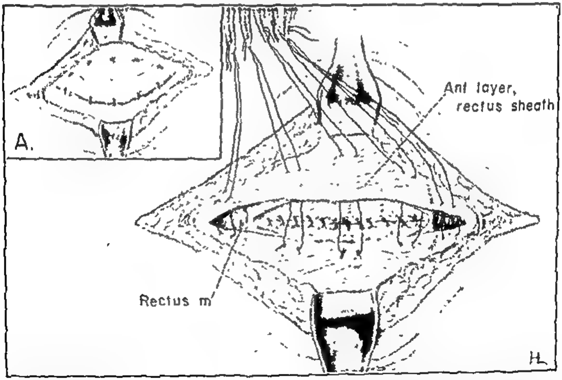

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the fascia. If gangrenous or perforated bowel is present, it is resected; the opening in the abdominal wall is closed with a few interrupted sutures and the hernia is repaired later.

After the sac has been isolated and the fascial ring exposed, the fascia adjacent to the defect is freed up for a distance of 3 to 4 cm. After the fascia has been carefully cleared of fat and areolar tissue, the sac is incised near the edge of the ring, everted, and any adherent contents are freed under direct vision. Again, if the sac contents are only omentum, the adherent portion may be ligated and removed with the sac. The remainder of the omentum is allowed to fall back into the peritoneal cavity. The sac is then excised near its junction with the fascial ring, enough peritoneum being left to assure a good closure.

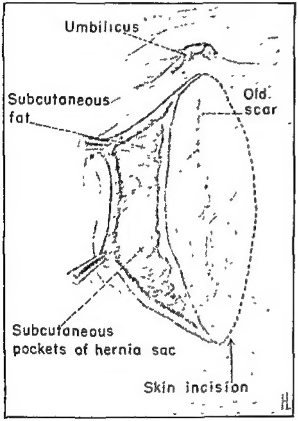

Fig 543.

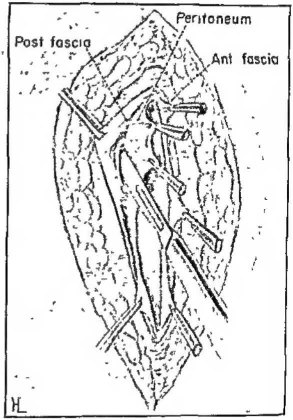

Fig. 544.

Fig 543.—Incisional hernia. Excision of the old scar by an elliptical incision *Note the subcutaneous ramifications of the sac.*

Fig 544 —Ventral hernia The sac has been excised The peritoneum is freed away from the fascia to allow closure in layers

An attempt is then made to isolate the various layers of the abdominal wall so that the peritoneum may be separated from the undersurface of the fascia (Fig. 544), and the fascia, itself, undermined on each side sufficiently far to obtain enough relaxation to overlap the two flaps for 2 to 3 cm The sac neck is then closed as in a laparotomy If sufficient fascia is present to bridge the defect without tension, the two edges are imbricated by insertion of sutures similar to those described under umbilical hernia repair (Fig. 545). Nonabsorbable sutures should always be used. If there is not sufficient fascia to allow imbrication of the two layers, relaxing incisions in the two anterior rectus sheaths may be made. If such incisions are

not feasible, or if they would not allow enough relaxation, it may be necessary to resort to the use of fascial strips or grafts to fill the defect. As previously mentioned, however, because of atrophy of the fascia or the likelihood of infection, it is best not to use fascia. Cutis or whole thickness grafts or a sheet of tantalum mesh have been found to give better results than fascia and will produce an adequate

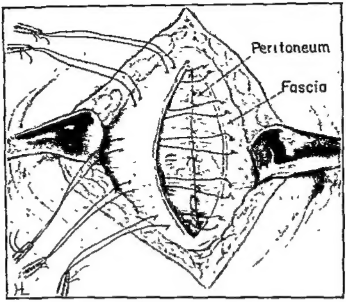

Fig. 545.—Ventral hernia. The peritoneum has been closed. A method of imbricating the fascia is shown

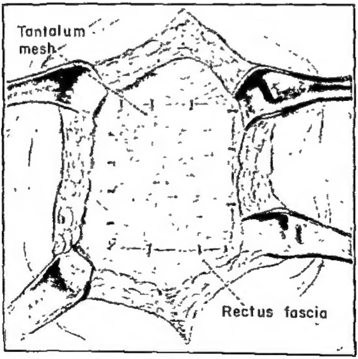

Fig 546.—Ventral hernia. A piece of tantalum mesh gauze may be necessary to cover a defect after closure of the peritoneum.

repair (Fig. 546). It is essential that a firm and complete closure of peritoneum or fascia be present under the mesh to prevent loops of bowel from becoming attached to the undersurface. Drainage of the fatty layer will be beneficial. The details of these technics are similar to these previously described.

Another method of closing incisional hernias has been described by Cattell, in which no attempt is made to isolate the various layers of the abdominal wall. After the sac has been emptied, he approximates the peritoneum of the defect in a longitudinal direction with chromic catgut, including all layers of the abdominal wall attached to the hernial ring. The sac is cut away about 2 cm. from this suture line and the remaining portion of the sac is approximated immediately overlying the first suture. An elliptical incision is made in the fascia 2 cm. lateral to the new suture line, exposing the muscle. The medial layers of the incision are approximated. The muscle and fascia are then freed up, and each layer is approximated in order. If there is too much tension on the fascial closure, relaxing incisions are made lateral and parallel to the suture line. This repair actually gives five layers to the closure and is applicable to hernias of all sizes in any portion of the abdominal wall. It would seem that this procedure is preferable to the use of skin or metal grafts.

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